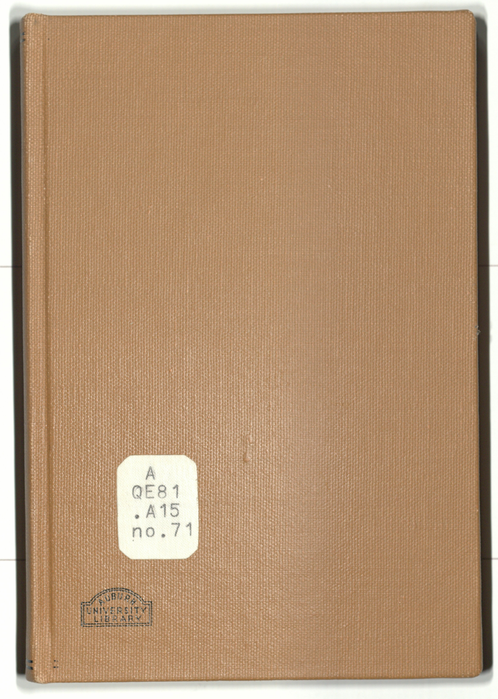
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GEOLOGICAL SURVEY OF ALABAMA

Philip E. LaMoreaux
State Geologist

DIVISION OF WATER RESOURCES

Doyle B. Knowles
Chief Hydraulic Engineer

BULLETIN 71

GEOLOGY AND GROUND-WATER RESOURCES OF THE ATHENS AREA, ALABAMA

By William M. McMaster

Prepared by the United States Geological Survey
in cooperation with the
City of Athens
and the
Geological Survey of Alabama

UNIVERSITY, ALABAMA

1963

STATE OF ALABAMA

Honorable George C. Wallace, Governor

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University, Alabama
March 5, 1963

Honorable George C. Wallace
Governor of Alabama
Montgomery, Alabama

Dear Governor Wallace:

I have the honor to transmit the manuscript of a report entitled "Geology and Ground-Water Resources of the Athens Area, Alabama" by William M. McMaster, with the request that it be printed as Bulletin 71 of the Geological Survey of Alabama.

The Athens area comprises the north-central part of Limestone County. The Fort Payne Chert is the most productive aquifer. The municipal wells and spring at Athens supply an average of about 931,000 gallons per day from the Fort Payne. The largest-capacity well in Limestone County is located in Athens and is planned as a source for municipal supply during 1962. This well obtains water from the Fort Payne and has been pumped at 1,800 gallons per minute. The mantle of residual material overlying the Fort Payne Chert and the Tuscumbia Limestone is a major ground-water reservoir and is the source of water for most domestic supplies. Ground water in the Athens area is generally of good chemical quality and is satisfactory for municipal and most industrial uses.

This report should be of assistance to water users in planning expansion of municipal and industrial water supplies in the area.

Respectfully,

Philip E. LaMoreaux

Philip E. LaMoreaux
State Geologist

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GEOLOGY AND GROUND-WATER RESOURCES OF THE ATHENS AREA, ALABAMA

By William M. McMaster

ABSTRACT

The Athens area occupies the north-central part of Limestone County and has an area of about 240 square miles. Athens, the county seat, is in the south-central part of the area and had a population of 9,325 in 1960.

The rocks of the area, chiefly limestone and cherty dolomite, range in age from Middle Ordovician to Late Mississippian and include the Chickamauga Limestone, the Chattanooga Shale, the Fort Payne Chert, and the Tuscumbia Limestone.

The rocks generally dip to the south and southwest at about 20 feet per mile but the regional dip is altered considerably by local structural deformation.

The Fort Payne Chert is the most productive aquifer in the area and Athens' municipal wells and spring supplied an average of about 931,000 gallons per day during 1960 from the Fort Payne. Well CT-25, located in Athens and scheduled to become a municipal source during 1962, had a drawdown of 27 feet after being pumped at 1,800 gallons per minute.

Test drilling in and near Athens indicates that large deep solution openings that potentially may yield large quantities of ground water are present only in synclinally low areas. Geologic structure influences the movement, occurrence, and availability of ground water by causing deflection of water away from structurally high areas into structurally low areas, where the greater thickness of the Fort Payne allows development of deeper, more extensive solution openings.

The mantle of residual material overlying bedrock of the Fort Payne Chert and the Tuscumbia Limestone is in places more than 80 feet thick, and the mantle serves as the major ground-water reservoir. Water in storage in the mantle is hydrologically connected to the solution openings in the bedrock and is an important source of recharge to the deeper aquifers.

Ground water in the Athens area is generally of good chemical quality. The total of dissolved solids in water obtained from the Fort Payne Chert is generally lower than that from the Chickamauga Limestone. Partial analyses of 25 water samples obtained from the Fort Payne Chert showed a comparatively low content of sulfate, chloride, iron, magnesium, and nitrate; and hardness ranged from 17 to 156 ppm (parts per million). Field analyses of 178 water samples from the Fort Payne showed a range of hardness from 10 to 326 ppm and an average of 56 ppm.

Partial analyses of 8 water samples from the Chickamauga showed nitrate in excess of 44 ppm in 3 samples. Hardness of these 8 samples ranged from 22 to 240 ppm. Field analyses of 57 samples of water from the Chickamauga showed a range of hardness from 28 to 338 ppm and an average of 136 ppm.

INTRODUCTION

LOCATION AND SIZE OF AREA

The Athens area, in north-central Limestone County, is defined for the purpose of this investigation as the area covered by four Tennessee Valley Authority 7½-minute topographic quadrangles: the Elkmont, Athens, Ripley, and Salem quadrangles. Limestone County is bounded on the north by the Alabama-Tennessee State line, on the east by Madison County, on the south by the Tennessee River, and on the west by Lauderdale County (fig. 1).

The Athens area includes about 240 of the 540 square miles of Limestone County. The Athens area contains 4 complete townships and parts of 8 others, from R. 3 W. to R. 6 W., and from T. 1 S. to T. 3 S.

Athens, the county seat, had a population of 9,325 in 1960 and is in the south-central part of the Athens area. Smaller communities included in the Athens area are Elkmont, Ripley, Salem, and Pettusville.

PURPOSE AND SCOPE

Because the demand for water by the growing population of Athens was approaching the maximum yield of its existing sources of supply during the period of heaviest usage, the city of Athens realized the need for an evaluation of its ground-water resources to determine if additional supplies could be obtained. In November 1958, the U.S. Geological Survey, in cooperation with the city of Athens and the Geological Survey of Alabama, began a detailed investigation of the ground-water resources of the Athens area as a part of the statewide program to evaluate the ground-water resources.

The purpose of the investigation was to relate the occurrence, availability, quantity, and quality of ground water to the geologic structure and stratigraphy of the area. The area in which detailed geologic work was done is slightly larger than the area included in the hydrology and test drilling phase of the investigation (pls. 1 and 7). The larger area of geologic study was necessary to define the geology surrounding Athens which would influence the occurrence and availability of water in the Athens area.

An interim report published by the Geological Survey of Alabama as Information Series 23, "Interim Report on Ground-Water

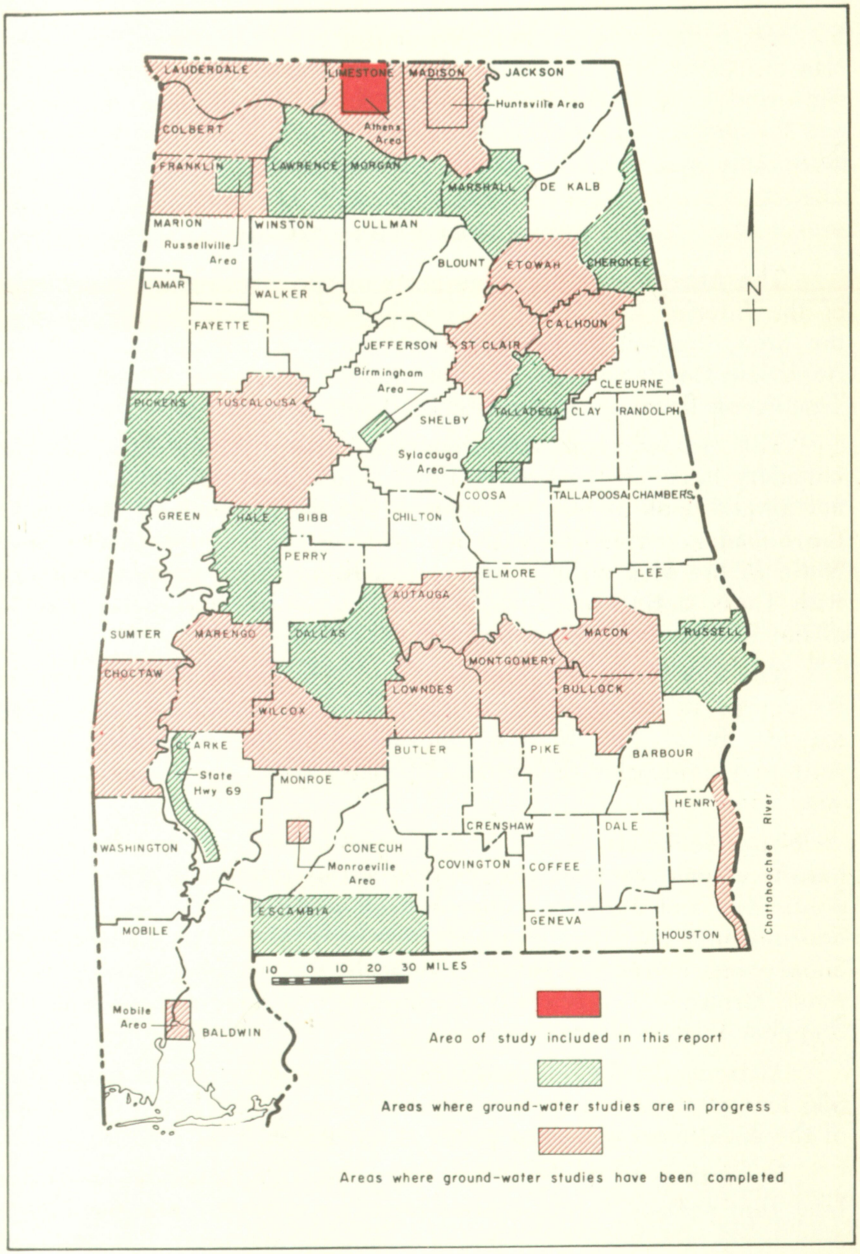

Figure 1.--Map of Alabama showing area of this report and areas of other ground-water studies.

Studies in the Athens Area, Alabama through January 1960" (McMaster, 1960), contains data obtained from wells and springs inventoried in the Athens area and the results of field chemical analyses for hardness and chloride content. The interim report contains data basic to, but not necessarily included in, this report.

TOPOGRAPHY AND DRAINAGE

The Athens area occupies parts of two physiographic sections of the Interior Low Plateaus province. The northwestern third of the area, drained by the Elk River and its tributaries, is in the Nashville Basin section. The remainder of the area, drained by the Tennessee River, is in the Highland Rim section.

The two sections are topographically distinct; however, the boundary between the two sections is irregular and its location is not agreed upon by physiographers. For the purposes of this report the boundary coincides with the outcrop band of the Chattanooga Shale in the area drained by the Elk River. This is in accordance with Theis' definition of the boundary of the Nashville Basin south of the Elk River (1936, p. 9-10, pl. 4; pl. 1).

The Elk River occupies a fairly wide valley through most of its course in the area; it meanders slightly and has a pronounced meander in T. 2 S., R. 5 W. Backwaters of the Tennessee Valley Authority's Wheeler Reservoir extend 24 miles upstream along the Elk River.

The Nashville Basin in the Athens area is characterized by narrow stream valleys, steep-sided hills, relatively steep stream gradients, and narrow, elongate drainage divides. Major streams draining into the Elk River are, from east to west, Ragsdale, Mill, Shoal, and Sulphur Creeks. Several of the smaller tributaries to these streams disappear into cavities along their stream beds and reappear farther downstream.

Altitudes in the Nashville Basin of the Athens area range from 556 feet at the Elk River to about 850 feet in the northeast corner of the area, making a total relief of about 300 feet.

In contrast to the Nashville Basin section, relief on the Highland Rim section in the Athens area is subdued. This part of the area is characterized by a gently rolling terrain, broad low drainage divides, and low stream gradients, except in areas near the Elk River where stream gradients are steeper and topography is more

rugged. Major streams draining into the Tennessee River are, from east to west, Piney, Swan, and Round Island Creeks. The U.S. Geological Survey, Surface Water Branch, maintains a stream stage recording gage on Piney Creek in sec. 7, T. 3 S., R. 3 W.

Altitudes in the Highland Rim section of the Athens area range from 600 feet where Round Island Creek leaves the area to slightly above 940 feet in the northeastern part of the area, making a total relief of about 340 feet.

CLIMATE

The Athens area has a temperate climate and abundant rainfall. Temperature extremes are rare, and, during winter, periods of freezing temperatures generally last less than 2 days. Long-term rainfall and temperature records are not available for the Athens area, but records for the Huntsville area, Alabama, 25 miles east of Athens, show an average annual rainfall of about 52 inches, an average summer temperature of 80°F, an average winter temperature of 46°F, and an annual average of 62°F. Periods of heaviest rainfall generally occur during January, February, and March; periods of lowest rainfall generally occur during July, August, and September.

TRANSPORTATION AND INDUSTRY

Two major highways, U.S. 72 and U.S. 31, cross the Athens area and intersect at Athens. Highway 72 serves east-west traffic, connecting Huntsville, 25 miles east of Athens, with the Florence-Sheffield-Tuscumbia area, 40 miles west of Athens. Highway 31 serves north-south traffic, connecting Athens with Decatur, 15 miles to the south, and Birmingham, 96 miles south of Athens. The proposed location of Interstate Highway 65 lies about 1 mile east of Athens. State and County roads in the Athens area are generally well maintained and most of them are paved. Access to all parts of the area is good.

A main line of the Louisville & Nashville Railroad, connecting Birmingham and Nashville, extends north and south across the Athens area. The railroad maintains a passenger and freight depot at Athens. Two major bus lines serve passenger traffic and operate a station at Athens.

Most of the residents of the Athens area are occupied in agriculture. Cotton, corn, beef and dairy cattle, poultry and poultry products are the chief items produced.

Industries in the area, all located in Athens, consist of a poultry-processing plant, two garment manufacturing concerns, a meat-packing plant, and a stove and heater manufacturing concern.

PREVIOUS INVESTIGATIONS

A short description of the geology and ground-water resources of Limestone County is given by W. D. Johnston, Jr., in a 1933 publication of the Geological Survey of Alabama, "Ground Water in the Paleozoic Rocks of Northern Alabama." Johnston gives information for several wells and springs inventoried in Limestone County during a reconnaissance study.

Several of the formations discussed by C. V. Theis in a 1936 publication of the U.S. Geological Survey, "Ground Water in South-Central Tennessee," are present in the Athens area, and his descriptions of the stratigraphy and water-bearing characteristics of formations in Giles and Lincoln Counties, Tenn., are applicable in the Athens area.

A comprehensive discussion of pre-Chattanooga stratigraphy and structure of central Tennessee, by C. W. Wilson, Jr., is contained in a 1949 publication of the Tennessee Division of Geology, "Pre-Chattanooga Stratigraphy in Central Tennessee." Several of the Ordovician formations described by Wilson are present in the Athens area and the geologic structure there is a continuation of structure of south-central Tennessee, which he described.

The phosphate deposits of the Chickamauga Limestone in Limestone County are discussed briefly in a paper by E. L. Hastings, published in the April 1959 Journal of the Alabama Academy of Science. Hastings summarizes the local Ordovician stratigraphy, describes the character of the deposits, and gives the results of analyses of 19 phosphate-bearing samples.

Criteria for differentiating the Fort Payne Chert and the Warsaw Limestone in Limestone County are listed by T. W. Daniel, Jr. and E. L. Hastings in a paper published in the April 1960 Journal of the Alabama Academy of Science.

A report "General Geology and Ground-Water Resources of

Limestone County, Ala.," by W. M. McMaster and W. F. Harris, Jr., containing the results of a reconnaissance type study of the geology and ground-water resources of Limestone County outside the Athens area, is published as County Report 11 of the Geological Survey of Alabama.

ACKNOWLEDGMENTS

The author expresses appreciation to Mr. John Marlin, manager of the Athens Water and Electric Department, and Mayor Arthur W. Stewart, for their cooperation and assistance during the project; to James C. Michael, Michael Drilling Co., for providing information on the depth to the Chattanooga Shale in several wells in the Athens area; to Mr. Harold N. Lovvorn, owner of well J-21, who kindly permitted installation and operation of a recording water-level gage on the well; and to Earl L. Hastings and Thomas W. Daniel, Jr. of the Geological Survey of Alabama, for their advice on mapping the Fort Payne Chert-Tuscumbia contact.

GEOLOGY

The exposed rocks of the Athens area range in age from Middle Ordovician to Quarternary and consist chiefly of limestone and cherty dolomite but include minor shale, siltstone, and sandstone. The oldest formation exposed in the area is the Chickamauga Limestone of Ordovician age. Successive formations are: the Chattanooga Shale of Devonian age; the Fort Payne Chert of Early Mississippian Age; and the Tuscumbia Limestone of Late Mississippian Age; and the residuum of Quarternary age.

The Athens area is on the southern flank of the Nashville dome, a low elliptical arch plunging southwestward. The strata of the Athens area dip generally to the south and southwest at about 20 feet per mile, but locally the rocks have been deformed considerably and their attitudes diverge sharply from the regional dip.

GEOLOGIC FORMATIONS AND THEIR WATER-BEARING CHARACTERISTICS

ORDOVICIAN SYSTEM

CHICKAMAUGA LIMESTONE

The Chickamauga Limestone, of Middle and Late Ordovician Age, crops out in valleys and along the lower slopes of hills in the northwestern third of the Athens area, where the Elk River and its tributaries have cut down through the overlying formations (pl. 1). The area of outcrop of the Chickamauga drained by the Elk River corresponds to the Nashville Basin physiographic section in the Athens area. The upper 20 feet of the Chickamauga also is exposed in two smaller areas -- one in a large sinkhole in sec. 7, T. 1 S., R. 3 W., the other along the upper reaches of Piney Creek.

The stratigraphy of the Chickamauga is complex because the formation changes laterally and nearly identical lithologies are repeated vertically. Generally, identification of subunits within the Chickamauga is dependent principally on fossil content rather than on lithology. The Chickamauga has been subdivided in detail in central Tennessee (Wilson, 1949, p. 1-239) but no subdivision is made in this report.

The Chickamauga consists of a wide variety of calcareous rocks, ranging from nearly pure limestone to calcareous siltstone, but the most typical rock type is bluish-gray dense to crystalline thin-bedded fossiliferous limestone interbedded with thin beds of shale. Other common rock types include light-tan to brown dense limestone, orangish-tan to light-brown shale, and light-gray to brown calcareous siltstone. Beds range in thickness from less than 0.1 foot to about 3 feet. Crossbedding is a common feature throughout the Chickamauga. Chert is common as beds or nodules in the limestone and typically is dark gray and dense when fresh. A maximum of about 250 feet of the Chickamauga is exposed in the Athens area. Fossils are common to abundant except in the calcareous siltstones and include brachiopods, bryozoans, corals, gastropods, pelecypods, cephalopods, crinoids, and blastoids.

The Chickamauga weathers to a light yellowish-tan residuum, which has abundant small light-colored chert fragments scattered over the surface. The residuum is generally less than 20 feet thick and ledges and bluffs of fresh rock are common in most of the area of outcrop.

Limestone County's only active limestone quarry is in the upper beds of the Chickamauga on Sulphur Creek. Phosphate is present in some beds of the Chickamauga and imparts a reddish color to the rock in places. Commercial deposits may be present in the Athens area where the phosphate has been enriched by weathering and concentration (Hastings, 1959).

A section showing the lithology of the Chickamauga Limestone as exposed in an abandoned quarry north of Elkmont is described in the following:

Geologic section of Chickamauga Limestone exposed on hillside and in abandoned quarry, SW¼ sec. 17, T. 1 S., R. 4 W.

	Thickness (feet)
Chattanooga Shale	
Sandstone, light-brown, fine- to medium-grained, contains fragmentary conodonts	0.5
Chickamauga Limestone	
Covered interval	12
Limestone, light greenish-gray, finely crystalline, crossbedded	2.7
Covered interval	4
Limestone, light brownish-gray, crystalline, weathering to small slabs; shale partings	1
Covered interval	15
Limestone, light-gray, coarsely crystalline; poorly preserved brachiopods and bryozoans	2
Covered interval	8.3
Limestone, very light gray, slightly shaly, thin-bedded	1.3
Covered interval	3
Limestone, light-gray with reddish tint, finely crystalline, phosphatic, crossbedded; beds less than 1 foot thick	3.5
Covered interval	5.5
Limestone, brownish-gray, coarsely crystalline, nodular; shale and silt partings; contains abundant unidentified bryozoans	4
Covered interval	7
Limestone, light-gray, crystalline, irregularly bedded	3.2
Covered interval	8
Limestone, light- to medium-gray, coarsely crystalline, interbedded with shale. Forms prominent ledge at top of quarry	6
Limestone, light-yellow, weathers to medium gray and yellowish gray, very silty	5
Limestone, medium tannish-gray to grayish-blue and yellow, dense, thin-bedded; contains nodules of dark-gray dense chert	4.2

	Thickness (feet)
Chickamauga Limestone --Continued	
Limestone, medium-gray, granular, nodular; irregular silt partings; dark-gray dense chert nodules	2
Limestone, light reddish-brown, weathers dark-gray, granular, phosphatic; few fossils	3.4
Limestone, light- to medium-gray, very shaly; many poorly preserved fossils	.4
Limestone, light-gray to reddish-gray, phosphatic, coarsely crystalline	2.7
Limestone, gray to bluish-gray, very shaly, very fossiliferous, containing *Herbertella sinuata, H. frankfortensis, Zygospira recurvirostris, Heterotrypa parvilipora,* and *Cyclonema varioscum;* beds up to 2.5 feet thick weather to chips and slabs	7

The Chickamauga yields water in quantities sufficient for domestic and stock use. No wells of potentially large capacity are known in the Chickamauga of the Athens area. The relatively steep slopes of the outcrop area and the thin mantle of residual material over bedrock cause a large part of the rainfall to run off into surface streams, thereby decreasing potential recharge to the aquifer (water-bearing formation).

Small springs are common in the outcrop area of the Chickamauga. Typically, these springs flow less than 50 gpm (gallons per minute), although a few flow more than 100 gpm during periods of high water level. Discharges of most springs flowing from the Chickamauga fluctuate widely through the year. Blowing Spring (A-1, pl. 2) has an exceptionally high discharge during periods of high water level, and on January 11, 1960, was discharging about 3,300 gpm, but during periods of low water level the spring discharges less than 300 gpm. Blowing Spring is in a large area of rock collapse, southeast of which is a large sinkhole developed through the lower beds of the Fort Payne Chert and the upper 20 feet of the Chickamauga. A small intermittent stream disappears into the sinkhole. A large part of the discharge of Blowing Spring may be contributed by the disappearing stream during the winter and spring.

DEVONIAN SYSTEM

CHATTANOOGA SHALE

The Chattanooga Shale of Devonian age disconformably overlies the Chickamauga Limestone and crops out on slopes bordering

the outcrop area of the Chickamauga (pl. 1). It also is exposed in the two smaller areas described in the section on the Chickamauga.

Typically the Chattanooga is a dark-gray to black fissile bituminous pyritiferous shale locally containing thin beds of sandstone. The formation ranges in thickness from less than 1 foot to about 8 feet. In several places in the Athens area, however, the Chattanooga consists of dark-gray dolomite, conglomeratic dolomite containing rounded quartz grains, phosphate nodules, pyrite, specimens of the small gastropod *Cyclora minuta* (reworked from the underlying Chickamauga), and oolitic fossiliferous claystone and oolitic hematite. These lithologic characteristics occur interbedded with shale typical of the Chattanooga in an exposure in a road cut near New Garden Cemetery and are described below:

Geologic section of the Chattanooga Shale in road cut, SE¼SW¼ sec. 33, T. 1 S., R. 4 W.

	Thickness (feet)
Fort Payne Chert	
Clay, reddish-brown to light-red, contains abundant blocks of porous white chert	5 ±
Clay, dark-brown stained black in places, silty, contains casts of small crinoid stems and fragments of chert	1.5
Chattanooga Shale	
Shale, dark-gray to black, weathers green and brown, fissile, bituminous	1.7
Dolomite, medium-gray, crystalline; contains phosphate nodules and flakes and stringers of black shale; specimens of *Cyclora minuta* reworked from underlying Chickamauga Limestone in lower 0.3 foot; dolomite lenses out within 8 feet to either side of measured section	1.4
Dolomite, dark-gray, bituminous, irregularly bedded, lenticular, contains abundant phosphate nodules, rounded quartz grains, pyrite, and reworked *Cyclora minuta*	.8
Shale, dark-gray to black, weathers green and brown, fissile, bituminous	1.6
Covered interval	2
Chickamauga Limestone	
Limestone, medium-gray to grayish-blue, dense to medium crystalline, fossiliferous	15

The following section of the Chattanooga Shale is exposed in the same cut 10 feet from the southern end of the dolomite lens.

	Thickness (feet)
Hematite, dark-brown, oolitic; contains fragmentary conodonts	0.1
Claystone, light yellowish-brown, oolitic; contains abundant conodonts	.2
Hematite, dark-brown, oolitic; contains fragmentary conodonts	.2
Shale, dark-gray to black, fissile, bituminous	3
Covered interval	2.5

Cuttings obtained from the Chattanooga in 27 test wells drilled in and near Athens consist of dark-gray to greenish-gray dolomite, rounded quartz grains, phosphate nodules, pyrite, very minor amounts of gray shale, and specimens of *Cyclora minuta*. Only one test well, CT-16 (pls. 2 and 4), penetrated typical Chattanooga lithology, cuttings from which showed 1.5 feet of gray dolomite, quartz grains, phosphate nodules, pyrite, and specimens of *Cyclora minuta*, underlain by 4.5 feet of dark-gray fissile pyritiferous shale. Well CT-15, 1,400 feet northeast of well CT-16, penetrated 4 feet of Chattanooga with no shale lithology.

The Chattanooga Shale is a marker bed in drilling test wells in and near Athens. Plate 1 includes structure contours showing the configuration of the top of the Chattanooga Shale in the Athens area.

The Chattanooga Shale is not considered an aquifer in the Athens area because it is relatively impermeable and thin. Instead, it acts as a barrier to downward-moving water in the Fort Payne Chert. For this reason, springs are common within a few feet above the Fort Payne-Chattanooga contact throughout its outcrop area.

MISSISSIPPIAN SYSTEM

FORT PAYNE CHERT

The Fort Payne Chert of Early Mississippian Age, disconformably overlies the Chattanooga Shale, cropping out in an irregular band across the central part of the Athens area, and capping hills and ridges in the northwestern part of the area (pl. 1).

The Fort Payne consists predominantly of light-gray, bluish-gray, and greenish-gray dense to crystalline extremely siliceous dolomite and limestone. In many places the lower 10 to 30 feet of

the formation consists of grayish-green shaly cherty dolomite. Chert is abundant as nodules, geodes, and beds throughout the formation but is particularly concentrated in the lower beds. Outcrops of fresh rock are rare because a thick residuum mantles the bedrock in most of the area. Because the contact between the Fort Payne Chert and the Tuscumbia Limestone is exposed only in a weathered condition in the Athens area, the total thickness of the Fort Payne cannot be accurately measured. Based on measurements using the weathered contact, however, the Fort Payne ranges in thickness from about 70 to 170 feet in the Athens area. A fairly good section of the Fort Payne is exposed in a road cut and along a stream bed south of Big Creek in the western part of the area and is described below:

Geologic section of the Fort Payne Chert southeast of Elk River and south of Big Creek, in stream bed and road cut, SW¼ sec. 30 and NW¼ sec. 31, T. 2 S., R. 5 W.

	Thickness (feet)
Tuscumbia Limestone	
Residuum, clay, light reddish-brown, contains blocks of porous brown chert that contains matted fenestellid bryozoans	30 ±
Fort Payne Chert	
Residuum, clay, light-yellow to tan, interbedded with white dense blocky chert that contains silicified spiriferid brachiopods and corals	67
Chert, dark-gray, dense, weathers lighter gray	1
Dolomite, medium-gray, dense to finely crystalline, silty; dark-gray dense nodules of chert	3
Limestone, dolomitic, medium-gray, finely crystalline, siliceous; includes blebs and nodules of crystalline calcite	9
Limestone, dolomitic, and dolomite, medium-gray to greenish-gray, shaly, and siliceous; includes blebs and nodules of crystalline calcite and dark-gray dense chert nodules; some beds weather to slabs of light-brown chert	20
Dolomite, light-gray, finely crystalline; upper third weathers to slabs of light-brown chert	1
Chert, weathers light yellowish brown; includes graptolites	.4
Limestone, light-gray, dense	1.2
Dolomite, grayish-green to green, shaly, weathers dark-gray	1.7
Limestone, dolomitic, medium-gray, finely crystalline, shaly; includes calcite nodules, brachiopod fragments, and nodules and stringers of dark-gray dense chert	3.8

	Thickness (feet)
Fort Payne Chert--Continued	
Dolomite, light-gray, finely crystalline; includes calcite nodules and nodules and stringers of dark-gray dense chert	4.7
Dolomite, tannish-gray, shaly, siliceous, nodular	1.2
Chert, dark-gray to bluish-gray, dense; includes blebs and stringers of tannish-gray finely crystalline dolomite	4.1
Dolomite, medium-gray, shaly, nodular; includes dark-gray dense chert nodules	4.8
Chert, dark-gray, dense; includes blebs and stringers of tannish-gray finely crystalline dolomite, weathers to light gray to yellowish tan	4
Dolomite, light-gray, dense, siliceous, shaly, nodular; includes dark-gray dense chert nodules	2.5
Dolomite, light-gray, dense to finely crystalline, extremely siliceous; includes abundant chert nodules and calcite stringers	4.5
Dolomite, medium-gray, very shaly, nodular	.8
Dolomite, greenish-gray, shaly; includes abundant dark-gray dense chert nodules and crystalline calcite nodules	1.9
Chert, medium-gray, dense; includes blebs and stringers of tannish-gray finely crystalline dolomite	1.7
Dolomite, light-gray, dense; includes dark-gray dense chert nodules	1.2
Covered interval	10
Chert, dark-gray, dense	1.5
Dolomite, grayish-green, dense	.2
Chert, medium-gray, dense	.3
Dolomite, light-gray, very dense, siliceous	.4
Chert, dark-gray, dense	1
Dolomite, bluish-gray, very shaly, nodular	1.2
Dolomite, olive-green, shaly, extremely siliceous; includes chert geodes, nodules, and beds; poorly preserved specimens *Productus* (sp?)	1.9
Limestone, light bluish-gray to greenish-gray, shaly, siliceous	1
Chert, light tannish-gray, dense, weathers light tan	1.6
Dolomite, light-gray, finely crystalline	.5
Chert, dark-gray, dense, weathers light tannish gray	2
Dolomite, light-gray, finely crystalline; includes dark-gray dense chert beds and nodules	1.6
Chattanooga Shale	
Sandstone, light-brown, fine- to medium-grained	.3
Shale, black, fissile, bituminous	3

Chert in the Fort Payne typically is light to dark gray and dense when fresh but weathers to white and yellowish brown. Beds of chert range in thickness from less than 0.1 foot to about

1.3 feet (Daniel and Hastings, 1960, p. 260). Beds of limestone and dolomite of the Fort Payne range in thickness from less than 0.5 foot to about 4 feet. Shale beds, generally less than 2 feet thick, are present in places.

A variation in Fort Payne lithology is in the area drained by the eastern part of Sulphur Creek, where the basal 30 feet of the formation consists of light-green and white coarsely crystalline moderately cherty crinoidal limestone which weathers to an orangish-red residuum. This rock was quarried and cut for headstones and grave covers for the nearby New Garden Cemetery as early as 1850. The quarry has been inactive for many years.

The Fort Payne weathers to a thick cherty clay and silt residuum generally light yellowish brown but locally reddish brown. Chert beds commonly remain intact after weathering but tend to be deformed by slumping. The surface of the residuum is characteristically strewn with chert rubble, from flake to boulder size. Residual chert of the Fort Payne is characteristically white to yellowish brown, angular, dense, and contains casts and molds of large crinoid and blastoid stems, as large as 1 inch in diameter (Daniel and Hastings, 1960, p. 263). Brachiopods, corals, and bryozoans are also present but are less common.

The Fort Payne is the most productive aquifer in the Athens area. Wells penetrating the formation range in yield from a few gallons per minute for most domestic wells to 1,800 gpm for well CT-25 (pl. 2 and table 1).

Water occurs in the Fort Payne in openings enlarged by solution along joints of bedding planes. Most of the openings contain residual deposits of chert, clay, and silt; but open cavities exist in places. The potential yield of a solution opening of the type characteristic of the Fort Payne is governed by several factors, including size and depth of the opening, but also by the extent to which it is filled with residual material and the porosity and permeability of the material.

Springs discharging less than 100 gpm are common throughout the outcrop area of the Fort Payne. The largest spring discharging from the formation in the Athens area is Athens' municipal spring (J-34, pl. 2). Discharge at the spring is measured by a V-notch weir equipped with a recording water-level gage, installed by the city in December 1960. Peak discharge measured since then is 1,100 gpm on April 11, 1961. Minimum discharge during August and September is probably less than 500 gpm.

Table 1.--*Records of test wells drilled in the Athens area, Alabama*

Well numbers correspond to those in plates 2, 3, and 4; asterisk indicates chemical analysis given in table 3.

Altitude determined by aneroid barometer. (Accurate to ±5 feet)

Water-bearing unit: Mfp, Fort Payne Chert; R, residuum.

Well no.	Depth of well (feet)	Diameter of well (inches)	Water-bearing unit	Altitude of land surface (feet)	Remarks
* CT- 1	151.8	6	Mfp	683	Casing: 6-in. to 52 ft. Weathered water-bearing chert to 82.5 ft. Drawdown at 100 gpm, 47 ft. after 24 hours. Chattanooga Shale at 82.5 ft. See pl. 4 and 8.
* CT- 2	132.5	6	Mfp	707	Casing: 6-in. to 50 ft. Weathered water-bearing chert to 94 ft. Drawdown at 100 gpm, 32 ft. after 8 hours. Reflects pumpage at municipal well J-20 and well CT-25. Chattanooga Shale at 125.5 ft. See pl. 3 and 8 and fig. 4 and 6.
CT- 3	108.8	6	Mfp	726	Dry hole. Depth to bedrock, 70 ft. Chattanooga Shale at 93.3 ft.
* CT- 4	142.2	6	Mfp	725	Casing: 6-in. to 17 ft. Solution opening, 50 to 56 ft. Drawdown at 250 gpm, 52 ft. Chattanooga Shale at 139 ft. See pl. 3 and 8 and fig. 4.
CT- 5	136.0	6	Mfp	703	Casing: 6-in. to 60 ft. Solution opening, 73 to 73.5 ft. Estimated yield, 5 gpm. Chattanooga Shale at 126.3 ft. See pl. 3 and 8.
* CT- 6	82.3	6	Mfp	711	Casing: 6-in. to 31 ft. Solution opening, 44 to 46 ft. Estimated yield, 15 gpm. Chattanooga Shale at 73 ft. See pl. 3 and 8.
CT- 7	106.9	6	Mfp	695	Dry hole. Depth to bedrock, 49 ft. Chattanooga Shale at 101 ft.

CT- 8	136.1	6	Mfp	724	Dry hole. Depth to bedrock, 31.3 ft. Chattanooga Shale at 130 ft.
CT- 9	116.3	6	Mfp	702	Dry hole. Depth to bedrock, 47.5 ft. Chattanooga Shale at 114 ft.
* CT-10	125.0	6	Mfp	737	Casing: 6-in. to 24.5 ft. Solution opening, 38 to 39 ft. Estimated yield, 5 gpm. Chattanooga Shale at 119.7 ft. See pl. 3 and 8.
CT-11	100.7	6	Mfp	696	Casing: 6-in. to 49.5 ft. Solution openings, 60 to 60.5 ft. and 70 to 71 ft. Estimated yield, 5 gpm. Chattanooga Shale at 94.5 ft. See pl. 3 and 8.
* CT-12	135.3	6	Mfp	702	Casing: 6-in to 42.5 ft. Solution openings, 51 to 53 ft. and 56 to 58 ft. Estimated yield before air surging, 75 gpm. Surged with air, August 1960. Estimated yield after surging, 100 gpm. Reflects pumpage at municipal well J-33. Chattanooga Shale at 128.5 ft. See pl. 4 and 8.
* CT-13	117.5	6	Mfp	688	Casing: 6-in. to 81 ft., slotted from 60 to 81 ft. Weathered, water-bearing chert, 81 to 90 ft. Estimated yield, 200 gpm. Reflects pumpage at municipal spring J-34. Chattanooga Shale at 575 ft. See pl. 4 and 8.
CT-14	141.8	6	Mfp	667	Dry hole. Depth to bedrock, 42 ft. Chattanooga Shale at 137 ft.
* CT-15	125.0	6	R	678	Casing: 6-in. to 61.5 ft., slotted, 40 to 61.5 ft. Estimated yield, 50 gpm. Chattanooga Shale at 119 ft. See pl. 4 and 8.
* CT-16	128.5	6	R	681	Casing: 6-in. to 64.5 ft., slotted, 44 to 64.5 ft. Estimated yield, 100 gpm. Chattanooga Shale at 118.5 ft. See pl. 4 and 8.

Table 1.--*Records of test wells drilled in the Athens area, Alabama*--Continued

Well no.	Depth of well (feet)	Diameter of well (inches)	Water-bearing unit	Altitude of land surface (feet)	Remarks
* CT-17	80.2	6	R, Mfp	678	Casing: 6-in. to 62 ft., slotted, 40 to 62 ft. Solution opening, 68.5 to 70 ft. Drawdown at 60 gpm, 60 ft. Chattanooga Shale at 74 ft. See pl. 4 and 8.
* CT-18	141.3	6	Mfp	711	Casing: 6-in. to 44 ft. Solution opening, 90 to 95 ft. Estimated yield, 100 gpm. Chattanooga Shale at 139 ft. See pl. 3 and 8.
* CT-19	135.5	6	R	690	Casing: 6-in. to 39 ft., slotted, 29 to 39 ft. Estimated yield, 30 gpm. Chattanooga Shale at 129.5 ft. See pl. 4 and 8.
* CT-20	132.8	6	R, Mfp	725	Casing: 6-in. to 64 ft., slotted, 44 to 64 ft. Solution opening, 81 to 82 ft. Estimated yield, 60 gpm. Chattanooga Shale at 128 ft. See pl. 4 and 8.
* CT-21	84.5	6	R	715	Casing: 6-in. to 62.5 ft., slotted, 42 to 62.5 ft. Estimated yield, 20 gpm. Chattanooga Shale at 79 ft. See pl. 4 and 8.
CT-22	125.3	6	Mfp	754	Casing: 6-in to 39.5 ft. Solution openings, 55.5 to 56 ft. and 72.5 to 73 ft. Estimated yield, 5 gpm. Chattanooga Shale at 120 ft. See pl. 3.
CT-23	105.1	6	Mfp	729	Casing: 6-in to 39 ft. Solution openings, 56 to 57 ft., 62 to 63 ft., 72.5 to 73 ft., 83 to 84 ft., and 87 to 88 ft. Estimated yield, 100 gpm, Chattanooga Shale at 101 ft. See pl. 3 and 8.

CT-24	133.5	6	Mfp	720	Casing: 6-in. to 42.5 ft. Solution openings, 51 to 51 .5 ft. and 60 to 61 ft. Estimated yield, 40 gpm. Chattanooga Shale at 130 ft. See pl. 3 and 8.
* CT-25	135.0	15	Mfp	714	Casing: 16-in. to 62 ft. Solution openings, 64 to 66.5 ft., 67 to 68 ft., 79 to 80 ft., 86 to 87 ft., 93.5 to 99 ft., and 117 to 124 ft. Drawdown at 1,800 gpm, 27 ft. after 17 days developmental pumping. Chattanooga Shale at 130 ft. See pl. 3 and fig. 6.
CT-26	97.5	6	R	697	Casing: 6-in. to 34 ft., slotted, 24 to 34 ft. Estimated yield, 5 gpm. Chattanooga Shale at 64 ft. See pl. 4.
CT-27	143.4	6	Mfp	711	Casing: 6-in. to 52 ft. Solution openings, 89 to 89.5 ft., 94.5 to 95 ft., 113 to 113.5 ft., 118.5 to 120 ft., and 134 to 135 ft. Estimated yield, 50 gpm. Reflects pumpage at municipal well J-20 and well CT-25. Chattanooga Shale at 139 ft. See pl. 4 and 8.
CT-28	140.2	6	Mfp	702	Casing: 6-in. to 47 ft. Solution opening, 75 to 85 ft. Estimated yield, 100 gpm. Chattanooga Shale at 108 ft.

Water in a quantity adequate for domestic and stock use can be obtained in most areas underlain by the Fort Payne, at depths generally less than 80 feet. The amount of water that may be developed from a well tapping the Fort Payne depends upon the size and extent of the fractures and solution cavities penetrated. Water sufficient in quantity for municipal, industrial, and irrigation use is available in the Athens area.

Plates 3 and 4 show lithologic and electric logs of 22 test wells drilled through the Fort Payne Chert to the Chattanooga Shale in and near Athens. Locations of these wells and other wells and springs referred to in this report are shown in plate 2. Table 1 lists data regarding the 28 test wells drilled in the Fort Payne during the course of the project.

TUSCUMBIA LIMESTONE

The Tuscumbia Limestone, of Late Mississippian Age, is the youngest formation in the Athens area. It underlies soil cover principally along drainage divides in the southern part of the area, where it conformably overlies the Fort Payne Chert (pl. 1).

The only known exposures of Tuscumbia bedrock in the Athens area is at the spring basin at Hatfield Lake, SE¼SE¼ sec. 21, T. 3 S., R. 4 W. About 12 feet of the lower part of the Tuscumbia is exposed and consists of light-gray finely crystalline regularly bedded slightly cherty limestone. In the remainder of the area the Tuscumbia is represented by slightly to moderately cherty residual clay and silt which is typically orangish brown or reddish brown. In the southwestern part of the area, however, much of the Tuscumbia residuum is light yellowish brown, very similar to the residuum derived from the Fort Payne.

Residual chert of the Tuscumbia can be recognized by its content of matted fenestellid bryozoans, its rounded or subangular shape, rubbly, porous character and its orangish-brown to light-brown color (Daniel and Hastings, 1960, p. 263). The residuum generally has much less chert scattered over the surface than does residuum of the Fort Payne.

The Tuscumbia of the Athens area yields water mostly to dug wells and shallow drilled wells since the formation is represented primarily by residuum.

RESIDUUM

The mantle of residual material overlying bedrock in the Athens area, although not a geologic formation, has a major effect on the ground-water resources of the area and warrants discussion in this report.

Residuum is the weathered remains of bedrock from which relatively soluble materials have been leached by circulating water. The greater part of the residuum of the area is derived from the Fort Payne Chert and the Tuscumbia Limestone. Generally it is a heterogenous mixture of clay, silt, chert, and porous chert gravel zones, and is more than 80 feet thick in places. Figure 2 is a map showing ranges of thickness of residuum over bedrock in the Athens area. This map is based on records of wells in the Athens area (McMaster, 1960) and on records of test drilling.

Ground water occurs in the residuum mainly in the porous chert gravel zones. In areas where the residuum is 30 feet or more thick, relatively large amounts of water are stored. The gravel zones are apparently discontinuous and occur at various depths. A persistent zone of porous water-bearing gravel exists, however, at the base of the residuum, where active solution of the top of the bedrock is taking place. Many of the domestic and stock wells of the area, both dug and drilled, obtain water from this zone.

Although the volume of water stored in the residuum is large due to the thickness and extent of the material, wells obtaining water solely from the residuum rarely yield more than 50 gpm because of the low permeability of the gravel zones and the consequent inability of the residuum to transmit larger quantities of water.

GEOLOGIC STRUCTURE

The geologic structure of the Athens area is related to the Nashville dome, a low asymmetrical arch, whose crest lies in Rutherford and Bedford Counties, Tenn.

The long axis of the Nashville dome trends south-southwest through central Tennessee but curves to the west in Maury and Lawrence Counties, Tenn. Southeast of the curve of the axis of the dome in Giles and Lincoln Counties, Tenn., and in Limestone and Madison Counties, Ala., the geologic structure is characterized by northwest-trending minor anticlines and synclines superimposed on the regional dip (Wilson, 1949, p. 326 and pl. 1). Wilson

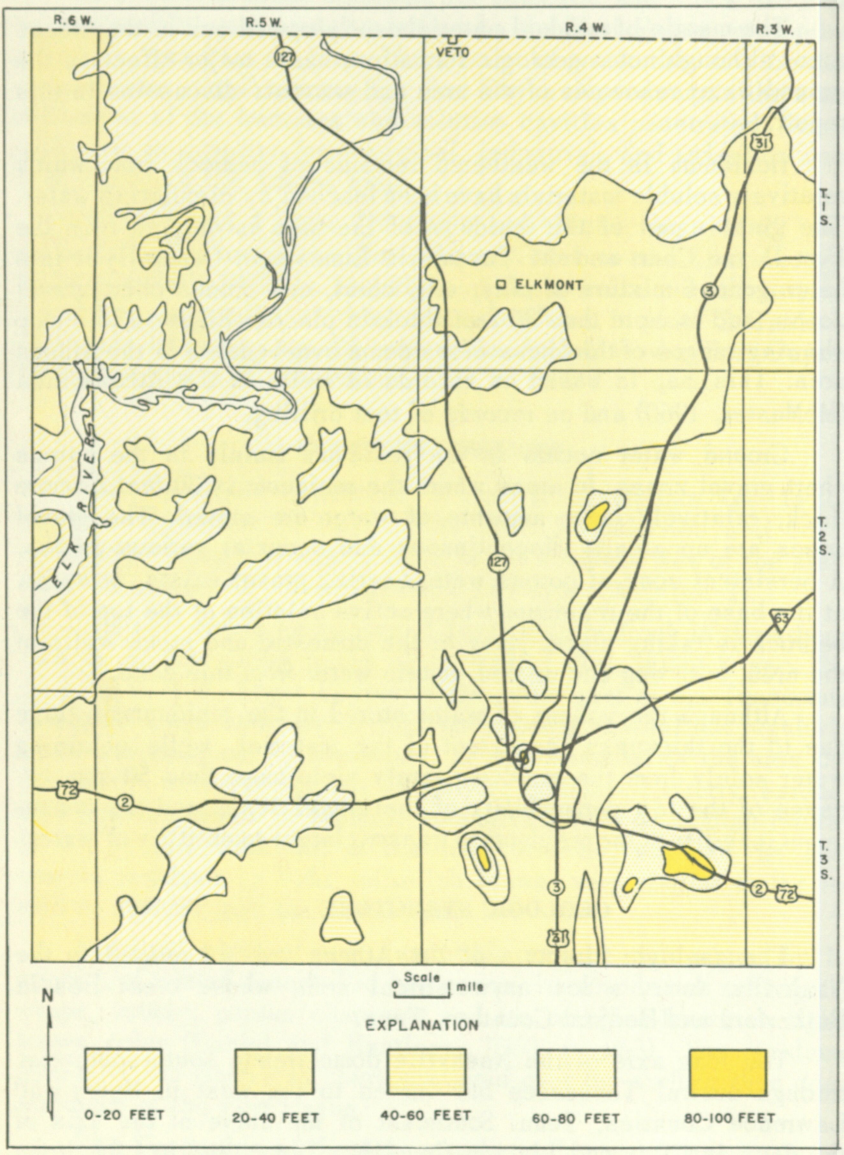

Figure 2.--Ranges of thickness of residuum over bedrock in the Athens area.

(1949, p. 333) states: "From the closely spaced and sharply asymmetrical character of these minor parallel folds it is believed that they resulted from vertical movement along a set of pre-existing northwest-southeast fractures in the rocks of the basement complex. Differential vertical movement along such buried fractures would produce asymmetrical folds by the passive draping of a mantle of sediments over the edges of individual elongated, interfault blocks of the basement rocks as they were being differentially adjusted. As these folds are most strikingly developed along the southern flank of the Nashville dome where the axis of this dome swings from a north-northeast strike to an east-west position, it is believed that the localized accentuation of differential vertical adjustment is definitely associated with the curving of the axis of the dome." Wilson further states that these minor structures originated during Late Ordovician time, because structural deformation can be correlated with variations in thickness of Upper Ordovician sediments in central Tennessee.

The geologic map of the Athens area (pl. 1) includes structure contours which show the configuration of the top of the Chattanooga Shale and locations of several minor structures. A structure contour map of Athens and vicinity (pl. 5), shows the structure in more detail. Most of the city of Athens is underlain by a shallow, irregular syncline, part of which forms a closed basin. The western and southwestern parts of Athens are underlain by structural highs.

The axes of these minor structures strike about N. 40° W.; this trend conforms to the axial strike of minor structures in Lincoln and Giles Counties, Tenn. (Wilson, 1949, pl. 1).

Topography reflects structure to some extent in the Athens area. Surface drainage by the smaller streams is generally away from structurally high areas toward structurally low areas. For example, the town of Elkmont is located on a topographic high as well as a structural high. The highest point in the area, in sec. 6, T. 1 S., R. 3 W., is on the structurally highest point. In Athens and vicinity the course of Town Creek conforms fairly closely to the axis of the syncline underlying Athens (pl. 5).

GROUND WATER

ORIGIN

The process by which water enters the earth to become ground water is known as recharge. Recharge is dependent upon precipitation, which in Alabama is almost entirely in the form of rain. Most of the water falling upon the land surface does not enter the ground but runs off into surface streams or is returned to the atmosphere by evaporation. A part of the water percolating down into the soil may be returned to the atmosphere by evaporation and transpiration and a part may be used to meet soil-moisture requirements. The remaining water moves down and becomes ground water upon reaching the surface of the zone of saturation, referred to as the water table or ground-water surface, below which interconnected voids and open spaces of the rock are filled with water.

The proportion of water from a rainfall which becomes ground water is governed by the nature of the rainfall--its intensity, duration, and distribution; and by air temperature and relative humidity, surface and soil conditions, and plant-moisture requirements. Because these factors vary seasonally recharge varies seasonally.

Generally during the period April through September rainfall typically occurs as relatively local brief intense showers and the total rainfall is lower than during the remainder of the year. The rate of evaporation is high as a result of higher temperature and lower relative humidity. Although surface and soil conditions are favorable for increased water absorption during this period, runoff is high due to the nature of the rainfall. Also during this period plant-moisture requirements are high.

During the period October through March total precipitation increases, typically occurring as steady general rain. The rate of evaporation is lower as a result of lower temperatures and higher relative humidity. The soil remains moist through a large part of this period and the nature of the rainfall and decreased plant-moisture requirements are favorable for increased recharge.

MOVEMENT OF GROUND WATER

Upon reaching the surface of the zone of saturation water begins to move laterally toward points of discharge. Discharge of ground water takes place naturally by springs, which are present where the water surface intersects the land surface, and by

transpiration from plants whose roots reach the zone of saturation; and artificially, by pumpage.

Maps showing the configuration of the water surface in Athens and vicinity on September 15, 1960 (pl. 6) and March 1, 1961 (pl. 7), represent the period of water-level high and period of water-level low, respectively, during the 1960-61 water year. The general direction of movement of ground water is along gradients at right angles to contour lines. The shape of the water surface conforms closely to the shape of the land surface throughout the Athens area.

Water-level contours (pls. 6-7) suggest that the direction of movement of ground water in Athens and vicinity is generally away from structurally high areas toward structurally low areas, concentrating ground water in the area of the synclinal axis. Consequently the hydrostatic head is greater and the area of recharge is larger in synclinal areas than in structurally high areas and the quantity of water moving through structurally low areas is correspondingly greater. As a result, solution development probably occurs more extensively in structurally low areas.

In the vicinity of Athens the configuration of the water surface is also related to geologic structure, as shown by comparison of plates 6 and 7 with plate 5.

The structural saddle forming the southeastern boundary of the closed structural basin underlying Athens acts as a partial ground-water barrier, retarding southward movement of the ground water. The areas in which the seasonal fluctuation of the water surface is less than 5 feet occur north and northwest of the barrier (pl. 5). The locations of the municipal spring and numerous smaller springs north of the structural saddle are related in part to the presence of the saddle.

STORAGE

Ground water in transit from recharge to discharge is referred to as being in storage. The amount of ground water in storage in an aquifer and available for man's use is dependent largely on recharge from precipitation and the capacity of the aquifer to receive, contain, and transmit water.

The results of test drilling and aquifer tests indicate that the residuum has a low transmissibility (ability to transmit water). However, the residuum is important for the volume of water it can hold in storage, for its ability to absorb water, for its ability to release water from storage, and for its hydraulic connection in many places over large areas with solution openings in the underlying Fort Payne Chert. The solution openings in the Fort Payne have low storage coefficients and high transmissibilities, however, the residuum acts as a sponge releasing water slowly from storage to satisfy the demands for water in the solution system in the Fort Payne.

The volume of water in storage in the residuum decreases during the period April to September as discharge exceeds recharge and wells and springs are largely dependent on water stored prior to periods of heavy demand. During the period October to March recharge exceeds discharge and the volume of water in storage increases.

AVAILABILITY AND STRUCTURAL CONTROL

A well drilled into limestone or dolomite to obtain water must penetrate one or more solution openings large enough to permit the required amount of water to flow into the well. Such openings generally occur in limestone and dolomite along joints or bedding planes which have been enlarged by solution.

The volume of ground water that can be removed in a given period of time from a well developed in a solution opening depends on the size and extent of the solution opening and the effective hydrologic extent of the opening, that is, the area from which the opening can receive water from storage. The effective hydrologic extent of the opening is controlled by its degree of interconnection with other openings and their ability to receive and transmit water from storage. That most, if not all, solution openings of the Fort Payne of the Athens area are interconnected to some extent is shown by the effect of a pumped well on surrounding observation wells (fig. 6).

In general, larger, deeper solution openings have a higher transmissibility and a greater effective hydrologic extent than smaller, more shallow solution openings. Although 1- to 2-foot-high solution openings at depths of less than 65 feet are common in

the Fort Payne throughout the Athens area, larger, deeper solution openings are less common and appear to underlie only limited areas.

Test drilling indicates that the large, deep solution openings are related to geologic structure. Of 28 test wells drilled in and near Athens, 17 wells penetrate solution openings. Ten of these wells have potential yields of 100 gpm or more. The wells with potential yields of 100 gpm or more are on or near the axis of the syncline or on the lower flanks of the syncline. Examples of high yield wells are municipal wells J-20 and J-33 (pl. 2). Well J-21, which was pumped at 250 gpm in 1950, and well J-35, the Gish Ice Plant well, which yields about 200 gpm, also are located on the lower flanks of the syncline.

Wells located on or near structural highs penetrate only small, shallow solution openings, most of which yield less than 50 gpm. Four test wells located on or near the axis of the syncline did not penetrate solution openings and seven test wells located on or near structural highs did not penetrate solution openings.

Athens municipal spring (pls. 1-5) is located near the synclinal axis north of the structural saddle, and locations of large springs in Limestone County outside the Athens area also appear to be controlled structurally (McMaster and Harris, 1962, p. 17).

FLUCTUATION OF WATER LEVELS AND THEIR CAUSES

Water levels in wells in the Athens area fluctuate in response to precipitation, pumpage from wells or springs, earthquakes, and loading of the land surface.

SEASONAL FLUCTUATION

The rate of change and total rise or decline of water levels vary seasonally. The seasonal fluctuation of the water surface of Athens and vicinity can be determined by comparing plates 6 and 7. Beginning in April water levels start down as the growing season begins and as recharge decreases. With minor rises caused by rainfall, the downward trend continues until September.

At the end of the growing season, and as recharge increases, water levels begin to rise. During October and November, rainfall has its most pronounced effect on water levels and rises of as

much as 6 feet in a 24-hour period occur in certain areas. Hydrographs of wells in and near Athens showing changes in water level and precipitation are shown on plate 8 and figure 3. Magnitudes of seasonal fluctuation are related to structural location. Within the area of the city of Athens underlain by the closed basin, water levels vary a maximum of 11 feet except at well J-21. At well J-21 the range of fluctuation is 13 feet, which is partially due to the effect of pumpage at municipal well J-20, 0.4 mile north of well J-21. Minimum fluctuation within the area underlain by the syncline is 4 feet, which occurs in an area north of the structural saddle and in the vicinity of well CT-4. In areas on and near structural highs, water levels fluctuate as much as 15 feet. Ranges of fluctuation of the water surface in Athens and vicinity are shown on plate 5.

PUMPAGE

Pumpage withdraws ground water from storage and, as a result, water levels decline in nearby areas. The extent of the affected area, or the area of influence, depends on the rate and duration of pumpage. The effect of pumpage on water levels is greatest at and near the pumped well, and decreases with distance from the well. In the Athens area, water levels decline at different rates in different directions away from the pumped well. During test pumping of well CT-25 drawdown was slightly greater to the northwest, at well CT-2, and southeast, at well CT-27, than to the northeast, at well J-21 (fig. 6). Pumpage also caused the water levels in the retaining basins at the municipal spring (J-34), 3,300 feet to the southeast, to decline. The distortion of the area of influence along a northwest trend is probably related to the increased transmissibility along the northwest-trending synclinal axes. When pumpage stops, water levels within the area of influence recover to approximately their original levels within a few hours.

Interference occurs where the areas of influence of two simultaneously pumped wells overlap. Where interference occurs the water levels decline at an accelerated rate.

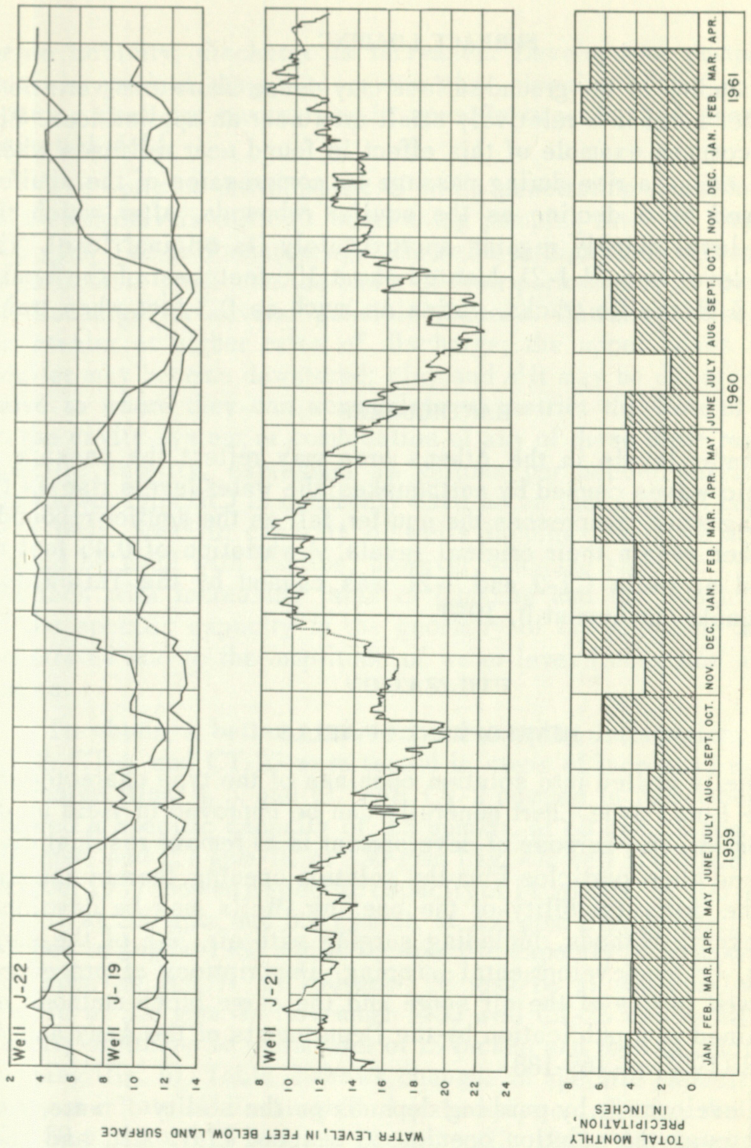
Well J-22
Well J-19
Well J-21
WATER LEVEL, IN FEET BELOW LAND SURFACE
TOTAL MONTHLY PRECIPITATION, IN INCHES
JAN. FEB. MAR. APR. MAY JUNE JULY AUG. SEPT. OCT. NOV. DEC.
1959
JAN. FEB. MAR. APR. MAY JUNE JULY AUG. SEPT. OCT. NOV. DEC.
1960
JAN. FEB. MAR. APR.
1961

Figure 3.--Changes in water level in wells J-19, J-21, and J-22 and precipitation at Athens, 1958-61.

SURFACE LOADING

Loading of the ground surface may cause short-term variations in water level in a relatively small area near an applied load. The most common example of this effect is found near railroads where trains cause a rise during passage by compression of the aquifer, followed by a decline as the aquifer rebounds, after which the water level quickly regains approximately its original level. The water level in well J-21, located about 100 feet west of the Louisville & Nashville tracks, varies as much as 0.3 foot when trains pass.

EARTHQUAKES

Water levels in the Athens area may reflect the passage of seismic waves caused by earthquakes; the water levels rise as the passing wave compresses the aquifer, fall as the aquifer rebounds, and then regain their original levels. A variation of 0.45 foot recorded at wells CT-2 and J-21 was caused by the Yellowstone earthquake on August 8, 1959.

UTILIZATION

DEVELOPMENT OF WELLS

Wells drilled into solution openings of the type characteristic of the Fort Payne Chert generally can be improved in yield by development. The purpose of development is to remove residual clay, silt, and chert particles from the solution opening, thereby increasing the transmissibility of the opening. Wells may be developed by several methods, including surging with air, use of the surge block, or by developmental pumping. Descriptions of procedures followed in use of the air surge and the surge block methods are contained in a publication by the Departments of the Army and Air Force (1957, p. 169-188).

Development by pumping depends on the ability of water moving through the solution opening to suspend clay, silt, and chert particles, the amount of suspended material varying with the velocity of the water. Wells are developed by stages of increasing rates of discharge. During the early part of each stage discharged water is turbid with suspended clay and silt, but as pumping continues the water gradually clears. When the discharged water shows little

or no turbidity, discharge is increased. Development pumping is done in gradual stages to ensure that plugging of the solution opening does not cause loss in specific capacity and decreased potential yield.

The optimum development of wells penetrating solution cavities commonly is difficult when using pumping rates of less than 300 gpm. The performance of such wells at high rates of discharge is difficult to predict on the basis of their performance at low rates of discharge for several possible reasons. Entrance losses may be greater at higher rates of discharge; the upper zones in the aquifer may become dewatered; clay and silt may be disturbed and move to where they can accumulate to restrict the flow of water to the cavity system; or combination of any of these three reasons. Specific capitity, expressed as gallons per minute per foot of drawdown, (gpm/ft.) is commonly used as an index to the capacity of a well. Specific capacity of wells tapping limestone aquifers should be used with caution, however, because specific capacity declines with increasing rates of pumping and the relationships of the specific capacity to the geometry of the solution system penetrated and to the amplitude of water-level fluctuation are not known.

To obtain a better evaluation of pumping information, wells CT-2, CT-4, and CT-25 were tested in steps of increased rates of discharge (figs. 4, 5, and 6). Well CT-2 pumped in November 1959 showed a specific capacity of 5.5 gpm/ft. at 60 gpm, 3 gpm/ft. at 100 gpm, and 2.7 gpm/ft. at 150 gpm (fig. 4). Well CT-4 pumped in October 1959 showed a specific capacity of 14 gpm/ft. at 100 gpm, 9 gpm/ft. at 200 gpm, and 5.2 gpm/ft. at 250 gpm (fig. 5). Well CT-25 pumped in August 1960 showed a specific capacity of 50 gpm/ft. at 100 gpm, 50 gpm/ft. at 200 gpm, 33 gpm/ft. at 300 gpm, and 29 gpm/ft. at 350 gpm. In November 1960 well CT-25 was redrilled by the city of Athens to a diameter of 15 inches and then developed by pumping (fig. 6). Table 2 shows changes in specific capacity with changes in rate of discharge during development. During the period of 5:30 p.m. to 8:15 p.m. on December 13, 1960, the pumping rate was maintained at 600 gpm; the specific capacity at this rate increased from 23 to 28 gpm/ft. The pumping level during this period rose about 5 feet, indicating that the production of the well was being improved by pumping; the specific capacity increased with each successive increase in discharge for the remainder of the test; at 1,000 gpm, the specific capacity was 47 gpm/ft. The increase

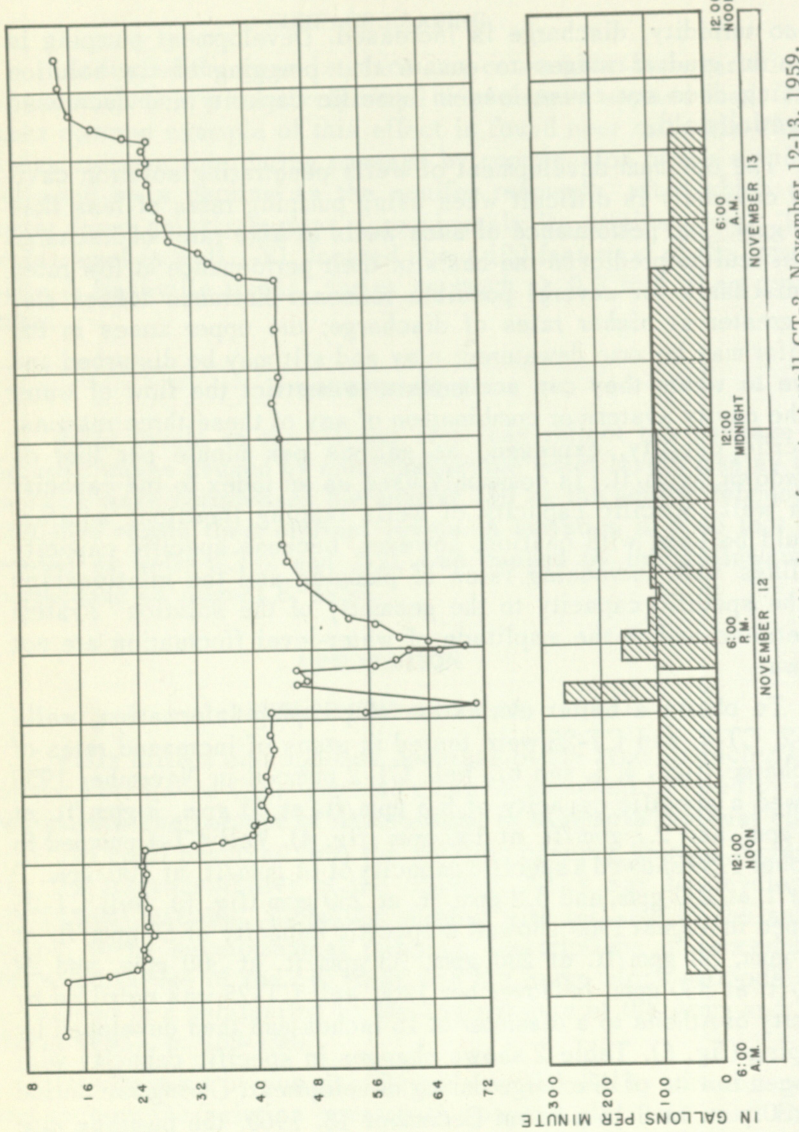

Figure 4.--Fluctuation of water level in and discharge from test well CT-2, November 12-13, 1959.

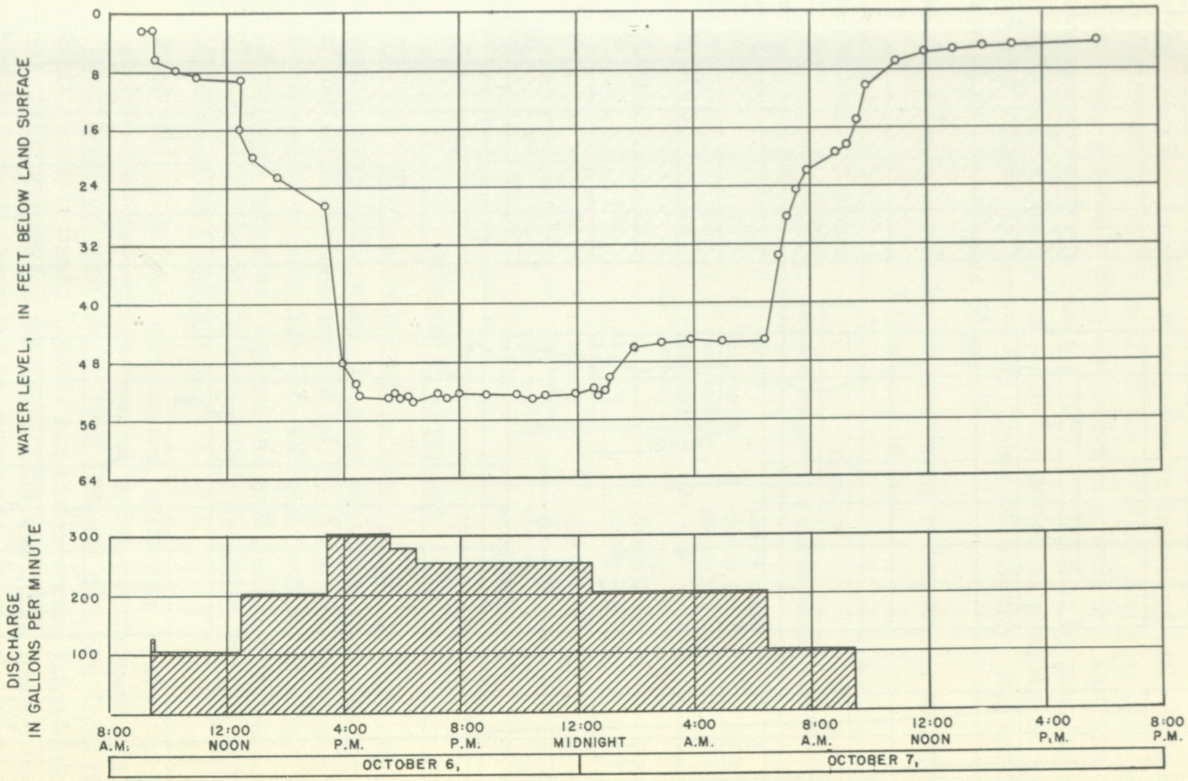

Figure 5.--Fluctuation of water level in and discharge from test well CT-4, October 6-7, 1959.

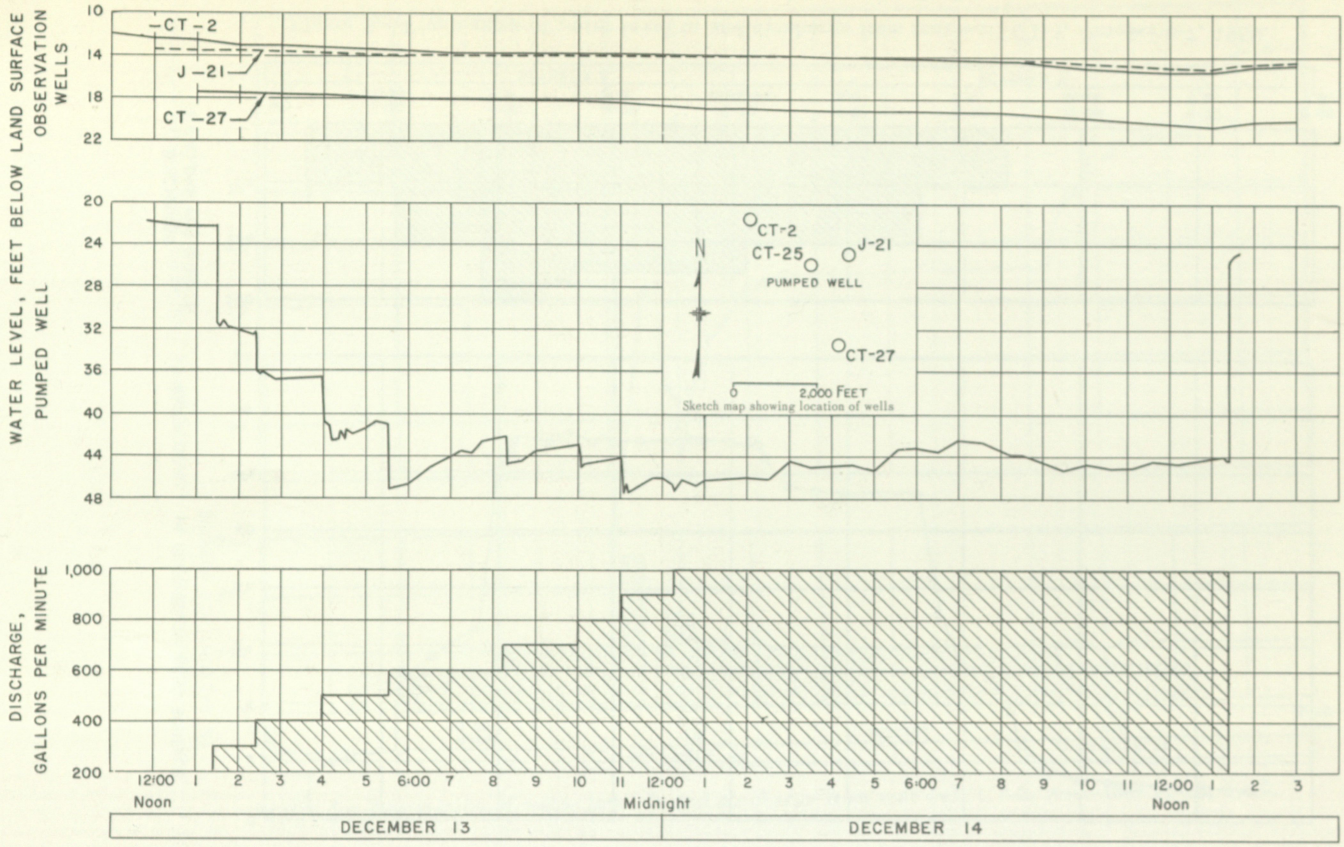

Figure 6.--Fluctuation of water levels due to developmental pumping well CT-25, December 13-14, 1960.

in the specific capacity in response to increased rates of pumping indicates the development of the solution cavity system; such an increase generally does not occur in a well that had been developed completely. In January 1961 development by pumping was resumed and, at the end of a 16-day period of pumping at 1,800 gpm and surging to remove all traces of turbidity, the specific capacity of the well was 66 gpm/ft.

Table 2.--*Changes in specific capacity during development of well CT-25, December 13-14, 1960*

Pumping stage (gpm)	Specific capacity (gpm/ft.)	Turbidity		Duration of stage (hours)
		start of stage	end of stage	
300	27	turbid	nearly clear	1
400	26	very turbid	cloudy	1 ½
500	25	very turbid	cloudy	1 ½
600 (start)	23	extremely turbid	- - -	
600 (end)	28	- - -	cloudy	2 ¾
700	32	slightly turbid	cloudy	1 ¾
800	34	slightly turbid	cloudy	1
900	36	very turbid	cloudy	1 ¼
1,000	47	turbid	nearly clear	13

MUNICIPAL WATER USE

The city of Athens obtained its water supply from the municipal spring until 1950, when, to meet the increasing demand for water, well J-20 was constructed (pl. 2). This well increased the city's supply by a potential 760,000 gpd (gallons per day). By 1957, additional water was needed and well J-33 was constructed (pl. 2), increasing the city's supply by a potential 360,000 gpd, or a total increase of 1,120,000 gpd.

When well J-20 was constructed, recording Venturi meters were installed at the well and spring and daily pumpage records have been kept for each since 1950. Annual pumpage from 1951 to 1960 is shown in figure 7. Water use has increased fairly steadily since 1951, except for the years 1954 and 1956, when drought resulted in unusual increases in water use. July and August are the months of highest use and February is generally the month of lowest use.

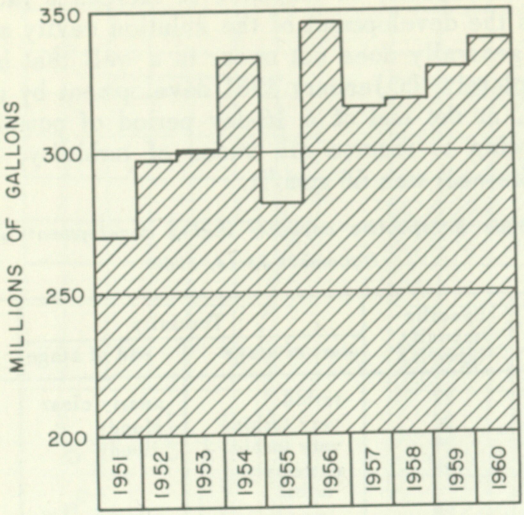

Figure 7.--Annual municipal pumpage at Athens, 1951-60.

Based on the city's record of pumpage, residents of Athens used an average of 931,000 gpd in 1960, or an average of 99 gpd per person. This average includes water used by the city's largest single consumer of water, Sweet Sue Poultry Co., which uses between 4 and 5 million gallons per month.

Water from each source is chlorinated and soda ash is added as the water is pumped into the distribution lines. These lead, depending on the demand, directly to the consumer or into either of two 750,000 gallon elevated storage tanks.

During 1959-60, Athens obtained about 47 percent of its water supply from the municipal spring, 42 percent from well J-20, and 11 percent from well J-33. The municipal spring will be used only during the period October to July after well CT-25 goes into operation because during extended heavy pumping at well CT-25, which will occur during the period of minimum flow at the spring, the spring will not be able to maintain water levels sufficiently high in the retaining basins to allow pumping. Well CT-25 will become a part of the municipal supply system during 1962 and will consist of a turbine pump which can be run by an electric motor capable of lifting 1,000 gpm or by a gas-operated engine capable of lifting 1,600 gpm. The gas-operated engine is to be used during the summer when demand is high and also will serve as a standby in case of electrical failure.

WATER SANITATION

Water sanitation is a significant factor in determining the value of a water supply. An abundant supply of water of good chemical quality is of little value if polluted. Pollution of ground water, unlike pollution of surface water, may require years or deccades for correction because of the slow movement of the water and retention of polluting materials. Consequently, pollution of ground water is much easier to prevent than to correct.

In a report to the United States Senate's Select Committee on National Water Resources, the Department of Health, Education, and Welfare (1960, p. 20) states: "Probably the most significant characteristic of ground water degradation is the fact that it is usually a cumulative, insidious process. Like cancer, it can best be treated in its incipient stages. Once well established, it is very difficult to correct. It is particularly important, therefore, that ground water quality be maintained at a high level and not be allowed to deteriorate through pollution of any sort. In many cases, maintenance of water quality becomes the limiting consideration in ground water basin operation."

In the Athens area, pollution potential is high where possible sources of pollution exist in combination with a relatively thin mantle of residuum, perhaps less than 40 feet thick, or where water levels are shallow, perhaps less than 15 feet below the surface. For example, municipal well J-33 is located in an area where water levels are within 4 feet of the surface during winter and spring and within 10 feet of the surface during summer and fall. The pollution potential of well J-33 is increased by its location near Town Creek (pl. 2) which, like many streams in this region, contain plankton. Although located in an area where the residuum thickness is greater than 40 feet, analyses of untreated water from the well have intermittently shown the presence of bacteria since its construction in 1957, and in August 1960 analysis showed bacteria present exceeding the maximum of 100 per cubic centimeter recommended by the Alabama State Department of Health.

An investigation to determine the sources of pollution was made by local representatives of the Alabama State Department of Health and officials of the city of Athens. The following conditions were reported by them in nearby areas north of well J-33:

1). In areas not served by sewer lines, improperly installed and inoperative septic tanks, some of which discharge raw waste

directly into Town Creek;

2). Abandoned dug wells, open or only partially covered, allowing direct access to ground water by surface water and in some cases used for disposal of garbage, refuse, etc.;

3). Houses without bathroom facilities or pit-privies; waste poured directly into Town Creek or its tributaries.

Analyses of a series of water samples collected along Town Creek showed a high bacteria count, and the count increases downstream. A sample collected from the creek at the site of well J-33 showed a count of 2,925 bacteria per cubic centimeter.

Probably most of the pollutants enter well J-33 by influent seepage from Town Creek while the well is being pumped. When the ground-water surface in the vicinity of the well declines below the level of the stream bed, the polluted surface water moves downward by way of solution openings.

The city's other sources of supply, well J-20 and the municipal spring (J-34), have remained free of pollution, and water from well CT-25, analyzed in January 1960, showed no bacteria. Both well J-20 and well CT-25 are in areas where the thickness of residuum is greater than 40 feet and where the water surface is more than 15 feet below the surface throughout the year.

Possibly, however, even these sources may become polluted in the future by conditions similar to those affecting well J-33. The number of residences using septic tanks is increasing continually in the areas adjacent to the northern city limits where a large part of the recharge to the basin underlying Athens occurs.

To prevent further pollution of its ground-water supply, the city of Athens is planning corrective measures: ordinances to correct existing unsanitary conditions and to govern future installation of septic tanks in areas within the city's jurisdiction not served by sewage lines; extension of sewage lines into the northern parts of the city; and ordinances to require filling of abandoned wells. With the subsequent elimination of sources of pollution and maintenance of high standards of water sanitation a continuous supply of safe water can be assured.

QUALITY OF WATER

Water falling on the land surface as rain contains some gases dissolved from the atmosphere, and additional gases are dissolved

as the water percolates through the soil zone, chiefly carbon dioxide given off by plant roots and decaying vegetable matter. Carbon dioxide combines with water to form carbonic acid, which greatly increases the solvent power of circulating ground water.

During its movement through and over rocks ground water comes in contact with various minerals, most of which are soluble to some extent in the acid-charged water. The chemical quality of water is influenced by a number of variables, including acidity of the water, minerals with which it comes in contact, rate of movement, length of time in contact with rocks, water temperature, and chemical reactions among the dissolved compounds.

Standards of chemical quality vary according to the purpose for which the water is to be used, such as for domestic, industrial, or irrigation use. The chemical quality standards of water for industrial use vary because of the variety of uses to which industry puts water.

Standards for drinking water established by the U.S. Public Health Service (1962) to control the quality of water supplied by common carriers commonly are quoted as limits for drinking water. According to these standards, supplies should not contain more than 0.3 ppm (part per million) of iron, 250 ppm of sulfate, 250 ppm of chloride, 0.8 to 1.7 ppm of fluoride (depending on the annual average of maximum daily air temperatures), 45 ppm of nitrate, and 500 ppm of total dissolved solids. Investigations since 1945 indicate that nitrate in domestic water supplies is related to the occurrence of cyanosis ("blue-baby disease") in infants whose feeding formulas are mixed with water containing more than 44 (45) ppm nitrate (Hem, 1959, p. 239). Three samples of ground water from the Athens area contained nitrate in excess of 45 ppm (table 3).

Partial analyses of water from 40 wells and springs in the Athens area show that most of the ground water is low in dissolved solids. Results of these analyses are shown in table 3.

Based on specific conductance water from the Chickamauga Limestone generally is more highly mineralized than that from the Fort Payne Chert. The three water samples containing nitrate in excess of 45 ppm were obtained from wells penetrating the Chickamauga. Partial analyses of 8 water samples from the Chickamauga showed a range of hardness from 22 to 240 ppm and an average of 98 ppm. Chloride content ranged from 0.5 to 56 ppm and averaged 15

ppm. A more representative range and average of hardness of the water and chloride content is shown by field analyses of 57 samples of water from wells and springs in the Chickamauga, which showed a range of hardness from 28 to 338 ppm and an average of 136 ppm. Chloride content ranged from 4 to 110 ppm and averaged 13 ppm (McMaster, 1960, table 1).

Hardness of water from wells drilled into the Chickamauga tends to increase with the depth at which water is obtained. Chloride content also increases with depth but less regularly than hardness. Figure 8 shows the average distribution of hardness and chloride content with depth based on field analyses of water from 32 wells penetrating from 9.6 to 300 feet of the Chickamauga (McMaster, 1960, table 1).

Partial analysis of water from well F-10 (table 3) is indicative of the quality of water obtained from wells drilled through the Chattanooga Shale and penetrating solution openings in the underlying Chickamauga. The extremely high nitrate content of the water from wells F-10, C-3, and B-53 may be caused by connection of the solution openings into which each well is drilled with one of the numerous small caves developed in the Chickamauga, many of which have fairly extensive deposits of guano, a high-nitrate substance composed of the excrement of bats.

Although from a carbonate aquifer, water from the Fort Payne Chert is comparatively low in dissolved substances. Partial analyses of 25 water samples from the Fort Payne showed a fluoride content ranging from 0 to 0.2 ppm and an average of 0.06 ppm. The maximum nitrate content was 13.0 ppm, and hardness ranged from 17 to 112 ppm and averaged 61 ppm. Chloride content ranged from 0 to 16 ppm and averaged 3.3 ppm. Field analyses of 178 water samples from the Fort Payne give a broader range and slightly different average for hardness and chloride content; hardness ranged from 10 to 326 ppm and averaged 56 ppm, and chloride content ranged from 2 to 103 ppm and averaged 12 ppm. (McMaster, 1960, table 1.)

The results of these analyses indicate chemical quality only and have no implication regarding bacteriological quality of water, except that high chloride content or high nitrate content may indicate pollution.

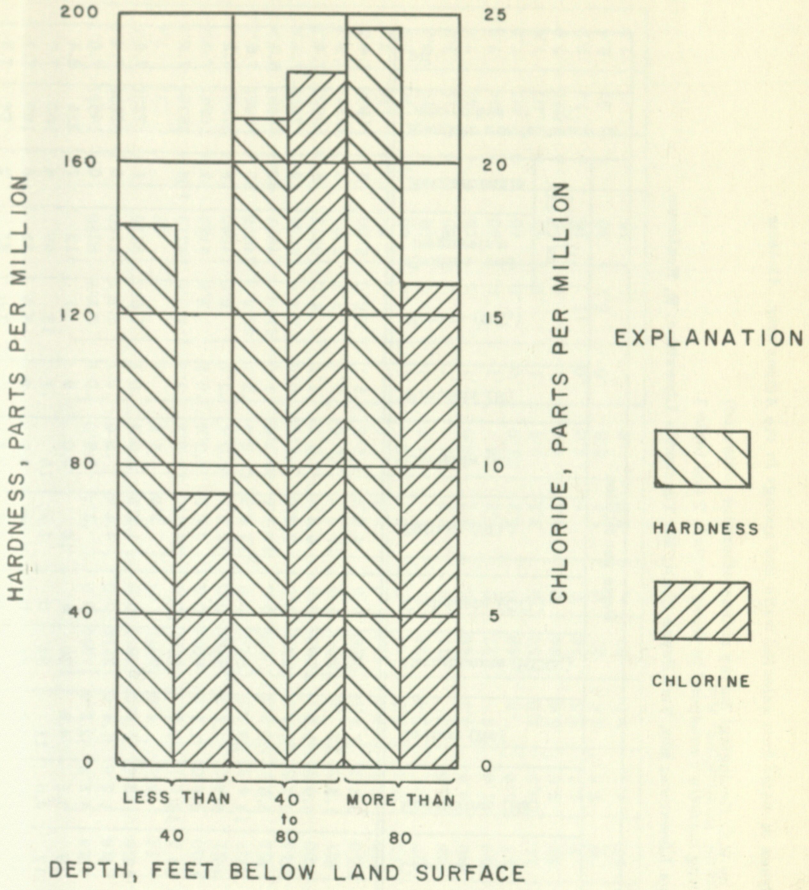

Figure 8.--Average distribution of hardness and chloride content with depth, Chickamauga Limestone.

Table 3.--*Partial chemical analyses of water from selected wells and springs in the Athens area, Alabama*

(Analyses by U.S. Geological Survey unless otherwise indicated)

Well and spring numbers correspond to those in plate 2 and table 1.

Water-bearing units: Oc, Chickamauga Limestone; Mfp, Fort Payne Chert; Mt, Tuscumbia Limestone; R, Residuum.

Well or spring no.	Water-bearing unit	Date of collection	Temperature (°F)	Parts per million										Hardness as $CaCO_3$		Specific conductance in micromhos at 25°C	pH
				Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Calcium and magnesium	Noncarbonate		
A- 1	Oc	5-26-60	59	0.01	15	3.3	1.1	55	0	4.8	0.5	0.1	3.9	51	6	110	7.4
B- 5	Oc	...do..	62	.00	6	1.5	77	196	4.0	16	1.0	.6	3.3	22	0	353	8.3
B- 36	Oc	5-27-60	60	.00	30	4.9	1.4	109	0	6.8	1.0	.1	.4	95	6	190	7.4
B- 50	Mfp	3-23-59	60	.00	30	2.7	1.3	102	0	3.2	2.5	.0	3.3	86	2	179	7.3
*B- 53	Oc	5-26-60	60	.00	9	5.8	45	8	0	10	56	.1	57	46	40	334	6.6
C- 3	Oc	4-20-61	60	.00	73	14	59	186	0	72	43	.3	97	240	87	749	7.6
*C- 6	Oc	5-27-60	64	.00	45	6.7	2.2	148	0	17	6.0	.2	.1	140	18	276	8.2
C- 29	Oc	...do..	61	.01	17	2.1	1.1	61	0	2.8	2.0	.0	.2	51	1	107	7.6
F- 10	Oc	...do..	62	.00	34	14	9.0	44	0	27	13	.2	111	142	106	362	7.3
								69									
G- 7	Mfp	3-25-59	57	.01	12	.7	1.1	39	0	1.2	2.0	.0	1.6	33	1	73	7.5
G- 40	Mfp	5-27-60	61	.01	5	1.2	1.4	21	0	4.4	.5	.0	3.7	17	0	51	7.0
G- 66	Mfp	3-25-59	62	.00	18	4.1	2.3	77	0	.8	2.8	.0	8.1	62	0	146	7.0
I- 5	Mfp	3-30-59	59	.00	39	3.5	4.8	120	4	18	2.0	2	.1	112	7	236	8.4
* J- 19	Mfp	3-23-59	62	.00	12	4.6	11	54	0	1.2	16	.1	13	49	4	160	7.7
J- 20	Mfp	...do..	60.5	.01	20	.5	1.3	56	0	.0	3.2	.0	5.6	52	6	109	7.3
J- 32	Mfp	4- 1-59	62	.00	14	2.4	.6	55	0	3.2	2.8	.1	2.0	45	2	98	7.8
J- 33	Mfp	3-23-59	62.5	.01	28	5.4	3.4	102	0	2.4	3.0	.1	4.0	92	8	179	7.9

J- 34	Mfp	...do..	61	.00	18	2.7	3.4	64	0	2.4	3.0	.0	3.2	56	4	121	7.7
J- 35	Mfp	3-30-59	'64	.00	18	3.6	1.4	74	0	2.4	2.8	.1	5.1	60	0	126	8.0
*J- 38	Mfp	3-23-59	62	.00	16	2.4	9.0	72	0	8.8	7.2	.1	.3	50	0	150	7.6
J-108	Mfp	...do..	62	.00	14	5.4	1.6	71	0	2.8	4.5	.1	.3	57	0	121	7.4
J-110	Mt	4-20-61	62	.00	3	1.1	3.3	11	0	1.6	5.2	.0	5.6	13	4	52	6.1
J-125	Mfp	5-27-60	62	.01	20	4.6	1.0	80	0	3.2	.5	.1	2.5	69	4	141	7.4
*K- 17	Mfp	3-26-59	60	.00	11	3.0	2.2	44	0	2.0	2.5	.1	6.0	40	4	93	7.4
K- 27	Mfp	5-27-60	62	.00	21	4.3	3.3	79	0	6.8	5.0	.1	4.2	70	6	161	7.3
CT- 1	Mfp	12- 2-59	60	.00	23	3.5	3.5	70	0	3.6	7.0	.0	10	72	14	167	7.4
CT- 2	Mfp	11-13-59	61	.00	15	4.5	.7	62	0	5.6	.0	.0	.0	56	5	111	7.4
CT- 4	Mfp	10- 7-59	60	.00	22	4.9	2.2	93	0	2.4	.5	.1	.0	75	0	155	8.0
*CT- 6	Mfp	5-26-60	60	.00	21	2.8	.6	78	0	1.6	.0	.0	.7	66	2	130	7.6
*CT-10	Mfp	...do..	61	.00	19	7.9	.9	98	0	3.2	.5	.1	.0	80	0	158	8.1
CT-12	Mfp	5-25-60	62	.00	26	7.1	1.4	114	0	3.2	.5	.1	.1	94	0	186	7.9
*CT-13	Mfp	6-27-60	62	.00	13	3.3	5.3	41	0	11	12	.1	.4	46	12	130	7.2
CT-15	R	5-25-60	61	.00	27	10	2.4	123	1	21	4.0	.1	1.9	108	6	222	8.3
* Do.	R	4-20-61	61	.00	28	3.6	10	111	0	7.2	12	.1	.2	85	0	218	8.2
CT-16	R	5-24-60	61	.00	40	4.4	4.3	140	0	5.2	6.0	.1	.1	118	4	248	7.6
* Do.	R	4-20-61	61	.00	29	1.8	18	122	0	.8	16	.1	.0	80	0	244	7.5
CT-17	R, Mfp	5-24-60	58	.00	13	1.8	.8	48	0	3.2	1.0	.0	.0	40	0	85	7.6
*CT-18	Mfp	4-21-61	61	.03	11	3.2	2.0	50	0	3.2	2.5	.1	.0	40	0	91	7.6
*CT-19	R	5-26-60	60	.00	53	5.8	6.6	194	0	4.8	4.0	.1	.0	156	0	320	7.9
*CT-20	R, Mfp	...do..	58	.00	7	2.2	3.3	26	0	.4	7.0	.0	11	26	4	74	7.2
*CT-21	R	4-20-61	61	.01	9	1.6	4.6	31	0	3.2	6.8	.0	6.2	30	4	91	6.6
[1] CT-25	Mfp	1- 4-61	61	.00	17	4.4	1.0	87	..	2.5	.0	...	...	56	..	...	7.0

* Sample collected by bucket.

[1] Analysis by Law Engineering Testing Company, Birmingham, Ala.

SUMMARY

The Athens area is underlain chiefly by limestone and cherty dolomite. The principal ground-water supply in the area is a combination of the Fort Payne Chert and the residuum that overlies it. The residuum acts as the ground-water reservoir, slowly releasing water over a large area to the underlying Fort Payne Chert. The water in the chert occurs largely in solution channels. Wells in the residuum commonly yield no more than about 25 gpm. Wells in the Fort Payne Chert yield as much as 1,800 gpm.

Solution openings less than 2 feet high and present at depths of less than 65 feet are common in the Fort Payne of the Athens area. Larger, deeper solution openings, which yield 100 gpm or more, are along the axes or the lower flanks of synclines. Locations of large springs also appear to be structurally controlled and to coincide with axes of synclines.

The direction of movement of ground water is closely related to geologic structure. Ground water is deflected from structurally high areas into structurally low areas. Ranges of seasonal fluctuation are similarly related, and are more narrow in structurally low areas, wider in structurally high areas.

Wells drilled into solution openings of the type characteristic of the Fort Payne Chert can generally be improved by proper development procedure which removes residual material from the solution opening and allows an increased volume of water to flow through the opening.

Water sanitation, or protection of the ground-water supply from pollution, is an important factor in determining the value of the supply because pollution of ground water, once established, is difficult to correct.

Water from the Chickamauga Limestone is generally more highly mineralized than is water from the Fort Payne Chert. Partial analyses of 8 water samples obtained from the Chickamauga showed nitrate present in excess of 44 ppm in 3 of the samples. Field analyses of 57 samples showed a range of hardness from 28 to 338 ppm and an average of 136 ppm.

Water from the Fort Payne Chert is generally of good chemical quality and is low in dissolved compounds. Field analyses of 178 samples of water from the Fort Payne showed a range of hardness from 10 to 326 ppm and an average of 56 ppm.

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38009

2 S.
3 S.

TRUE NORTH
3 1/4° E
MAG. NORTH

APPROXIMATE MEAN
DECLINATION 1958

Base modified from TVA
topographic quadrangles

Prepared
by
United States Geological Survey
in cooperation with
City of Athens and
Geological Survey of Alabama

CONFIGURATION OF THE WATER SURFACE AT ATHENS AND VICINITY MARCH 1, 1961.

By W. M. McMaster

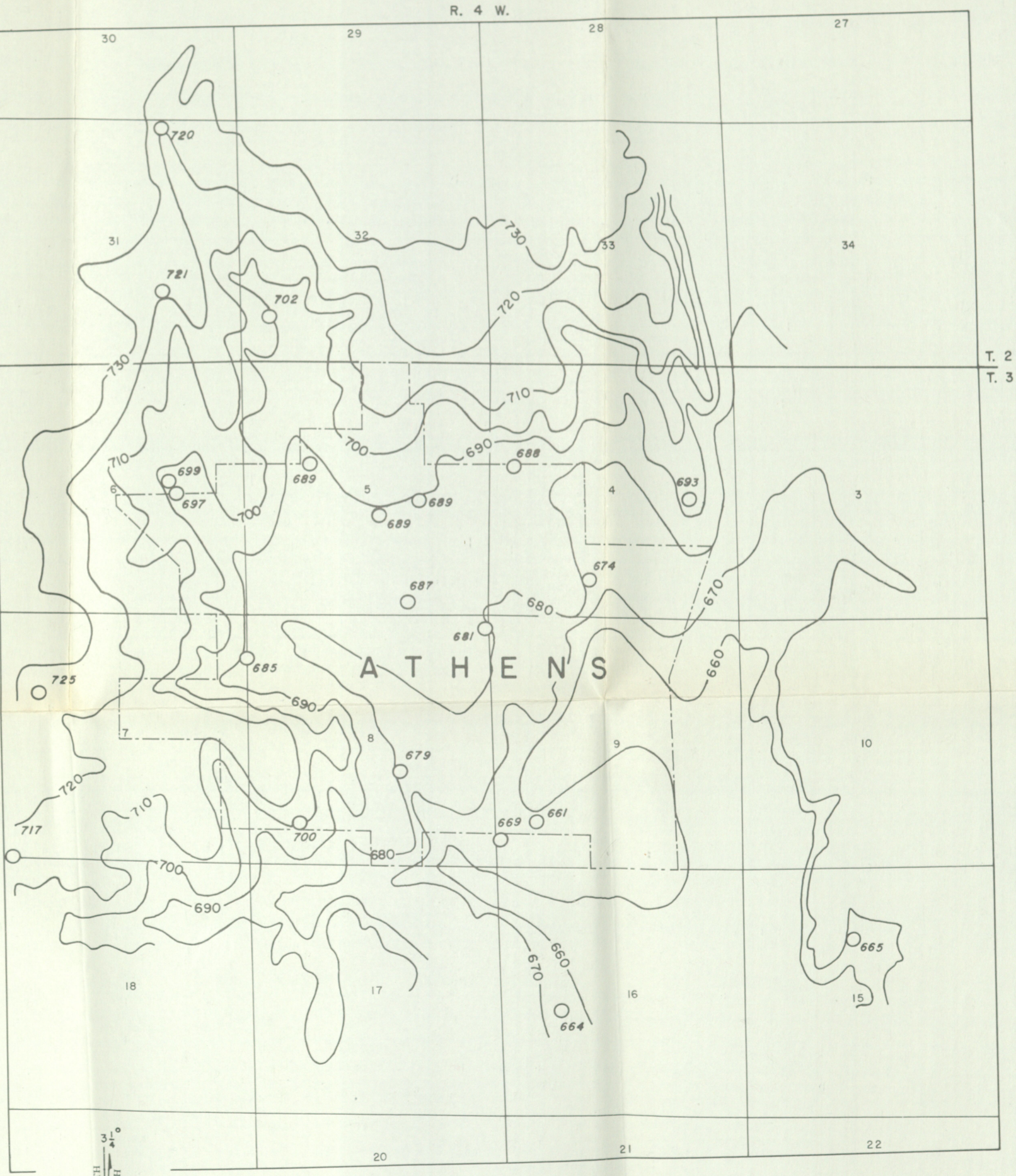
1 0 1 Mile

1962

EXPLANATION

677
Well; number is altitude of water level

700
Water-table contour; contour interval 10 feet, datum is mean sea level



3¼° TRUE NORTH MAG. NORTH

APPROXIMATE MEAN DECLINATION 1958

Base modified from TVA topographic quadrangles

Prepared by United States Geological Survey in cooperation with City of Athens and Geological Survey of Alabama

CONFIGURATION OF THE WATER SURFACE AT ATHENS AND VICINITY SEPTEMBER 15, 1960

By W. M. McMaster

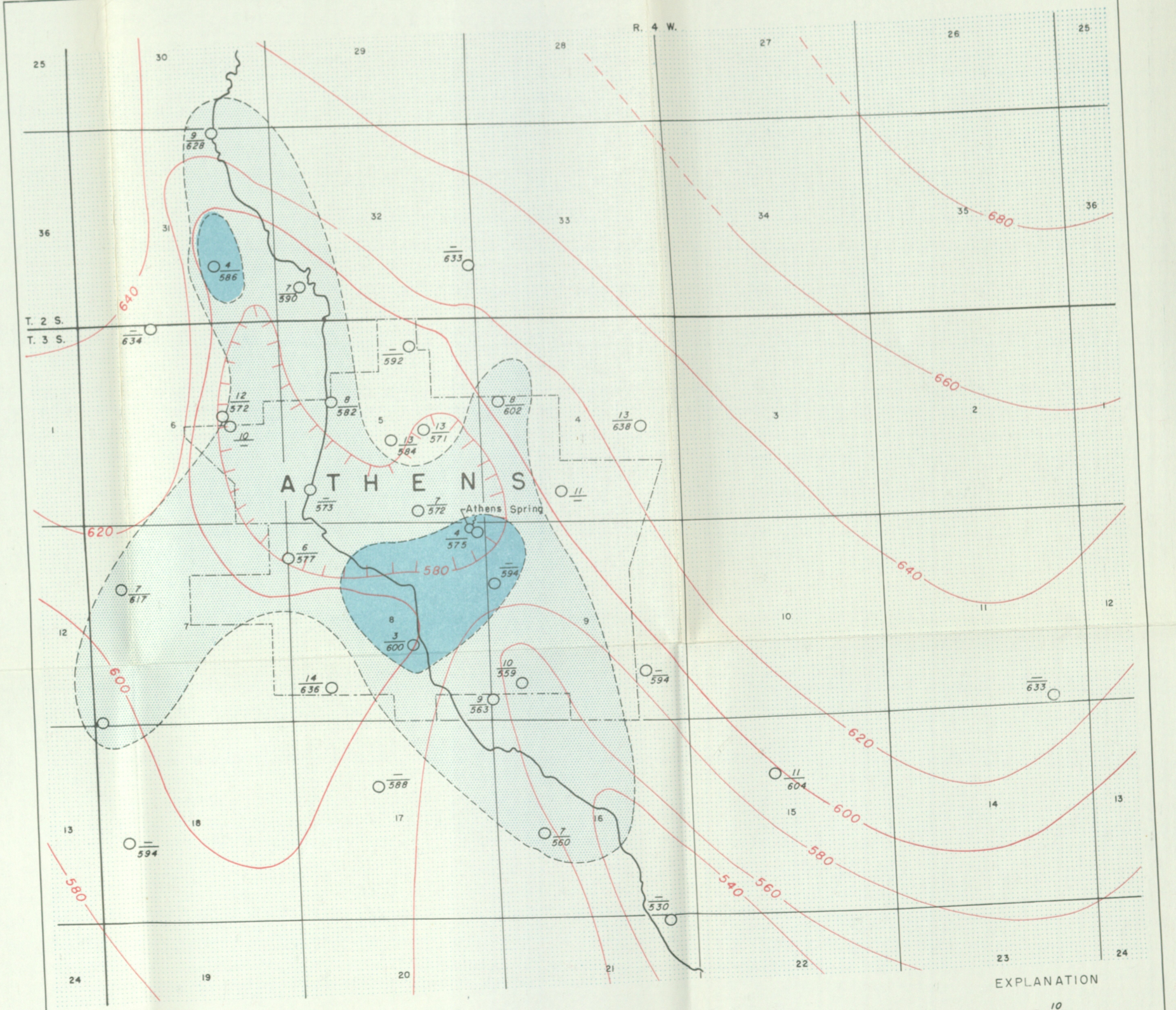
1 0 1 Mile

1962

EXPLANATION

674 — Well; number is altitude of water level

700 — Water-table contour; contour interval 10 feet, datum is mean sea level



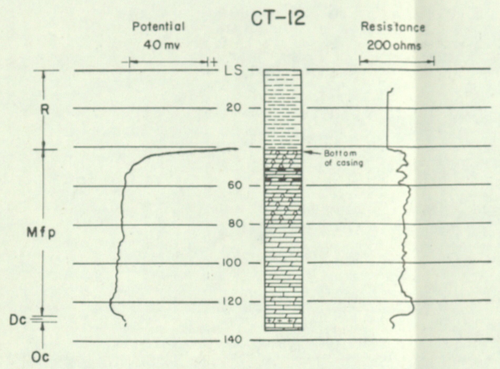
STRUCTURE-CONTOUR AND WATER-TABLE FLUCTUATION MAP SHOWING CONFIGURATION OF THE TOP OF THE CHATTANOOGA SHALE AND RANGES OF FLUCTUATION OF THE WATER SURFACE, ATHENS AND VICINITY

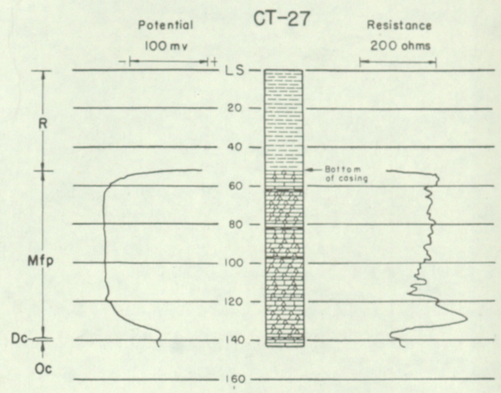
By W. M. McMaster

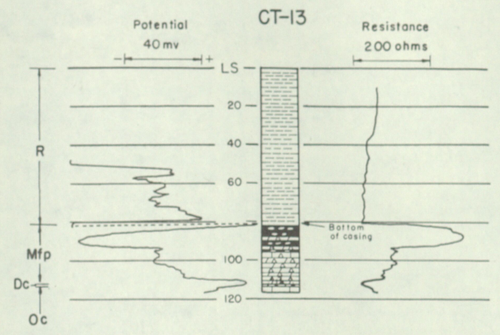
Base modified from TVA topographic quadrangles

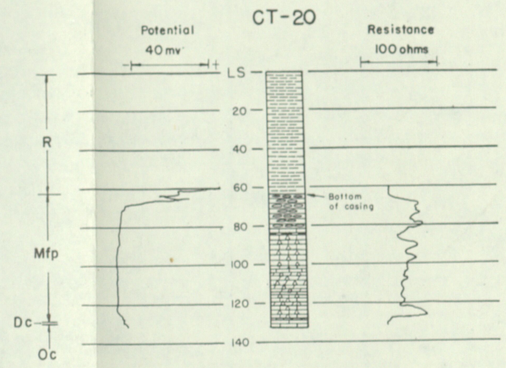
Prepared by United States Geological Survey in cooperation with City of Athens and Geological Survey of Alabama

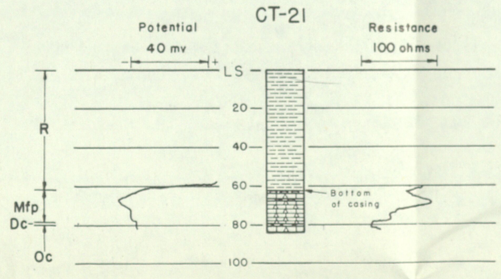
1962

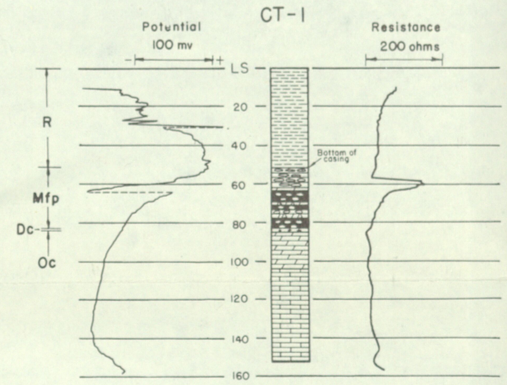


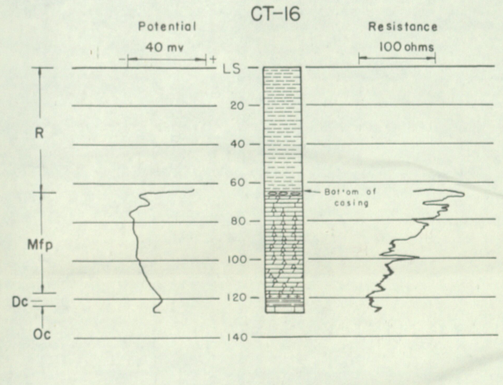


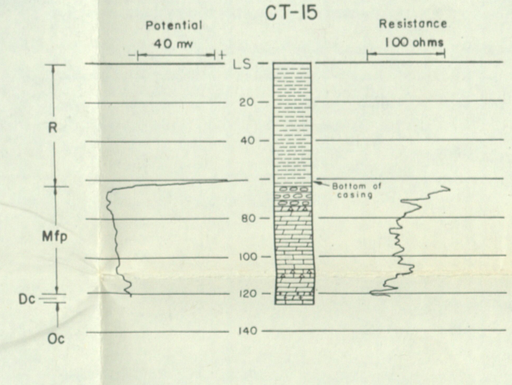


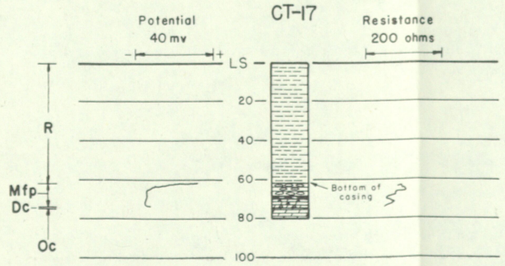


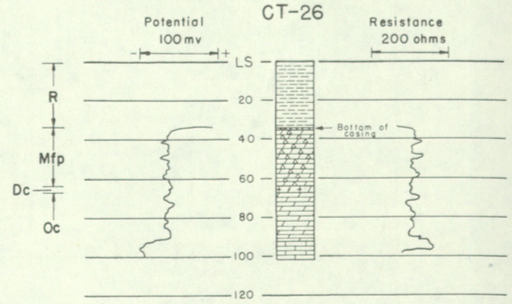


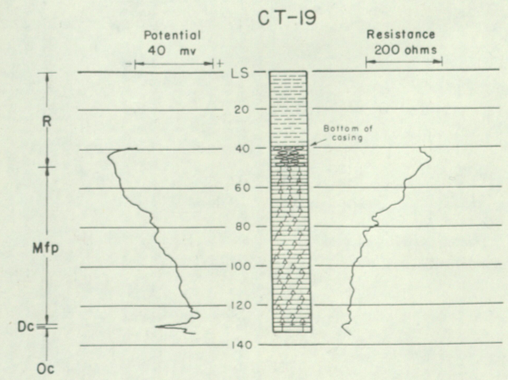




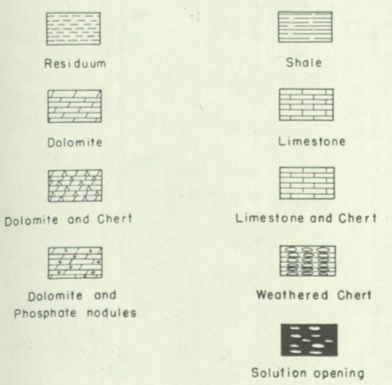






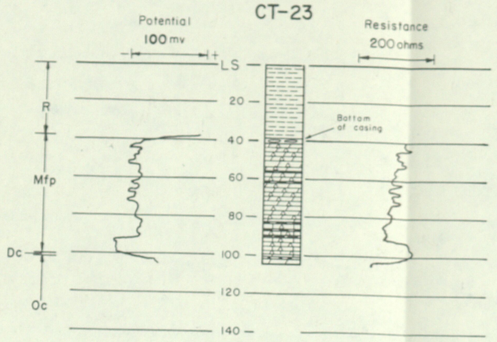


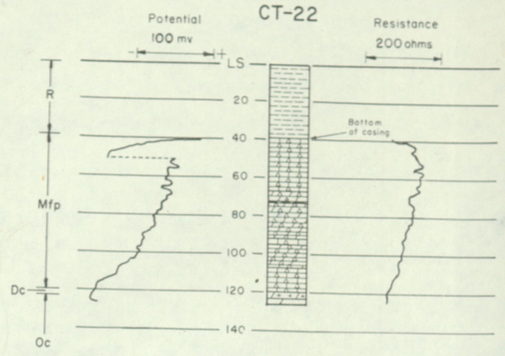
EXPLANATION

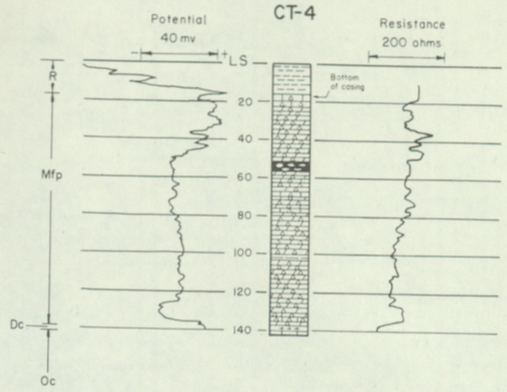


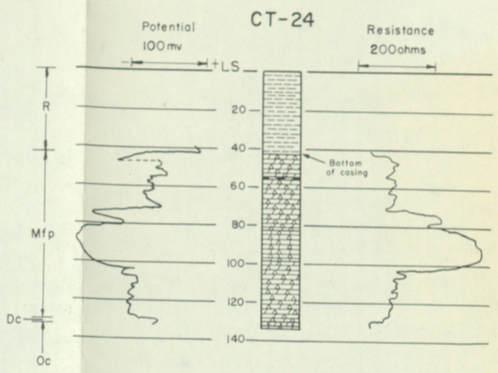
R — Residuum
Mfp — Fort Payne Chert
Dc — Chattanooga Shale
Oc — Chickamauga Limestone

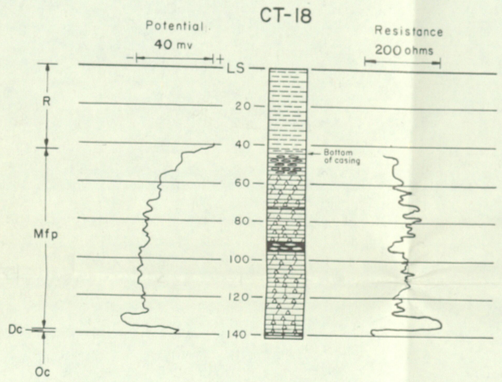
ELECTRIC AND LITHOLOGIC LOGS OF TEST WELLS AT ATHENS

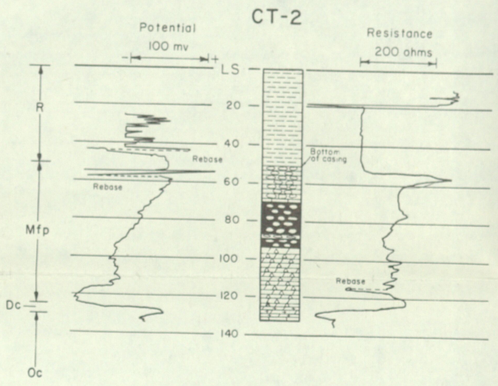


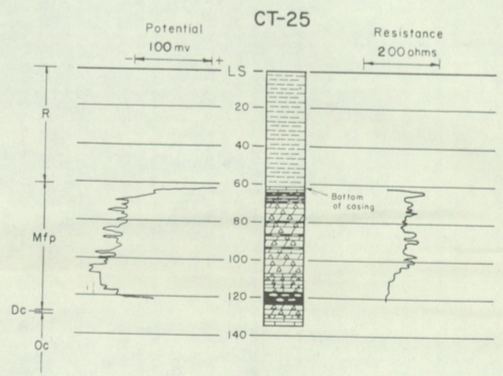


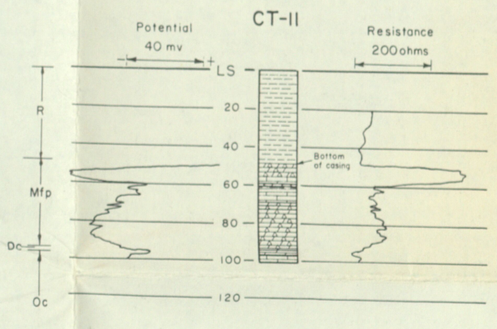


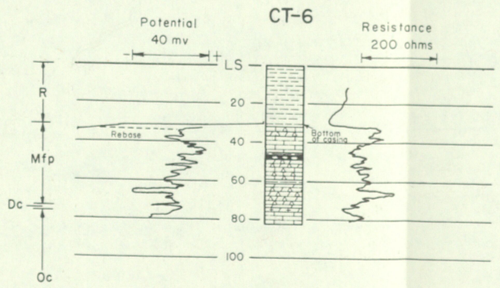


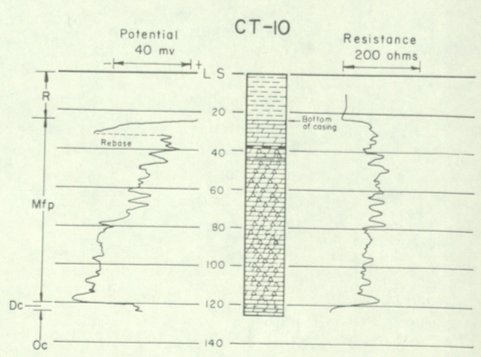


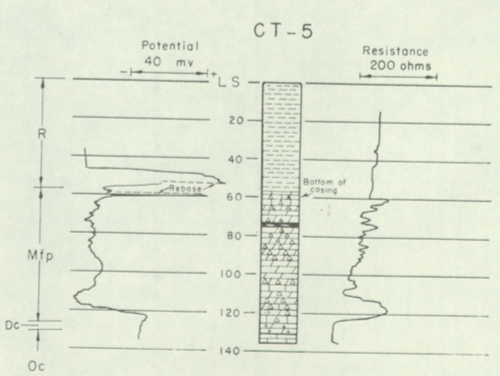




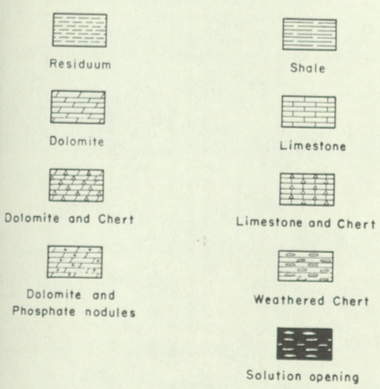








EXPLANATION



R — Residuum
Mfp — Fort Payne Chert
Dc — Chattanooga Shale
Oc — Chickamauga Limestone

ELECTRIC AND LITHOLOGIC LOGS OF TEST WELLS AT ATHENS

WELLS AND SPRINGS IN THE ATHENS AREA REFERRED TO IN THIS REPORT

Base modified from TVA topographical quadrangles

Prepared by United States Geological Survey in cooperation with City of Athens and Geological Survey of Alabama

APPROXIMATE MEAN DECLINATION 1958

Scale 1 0 1 Miles

EXPLANATION

Municipal, industrial or irrigation well

Domestic or stock supply well

Spring

Test well

(125) Number indicates water analyzed

Primary paved road

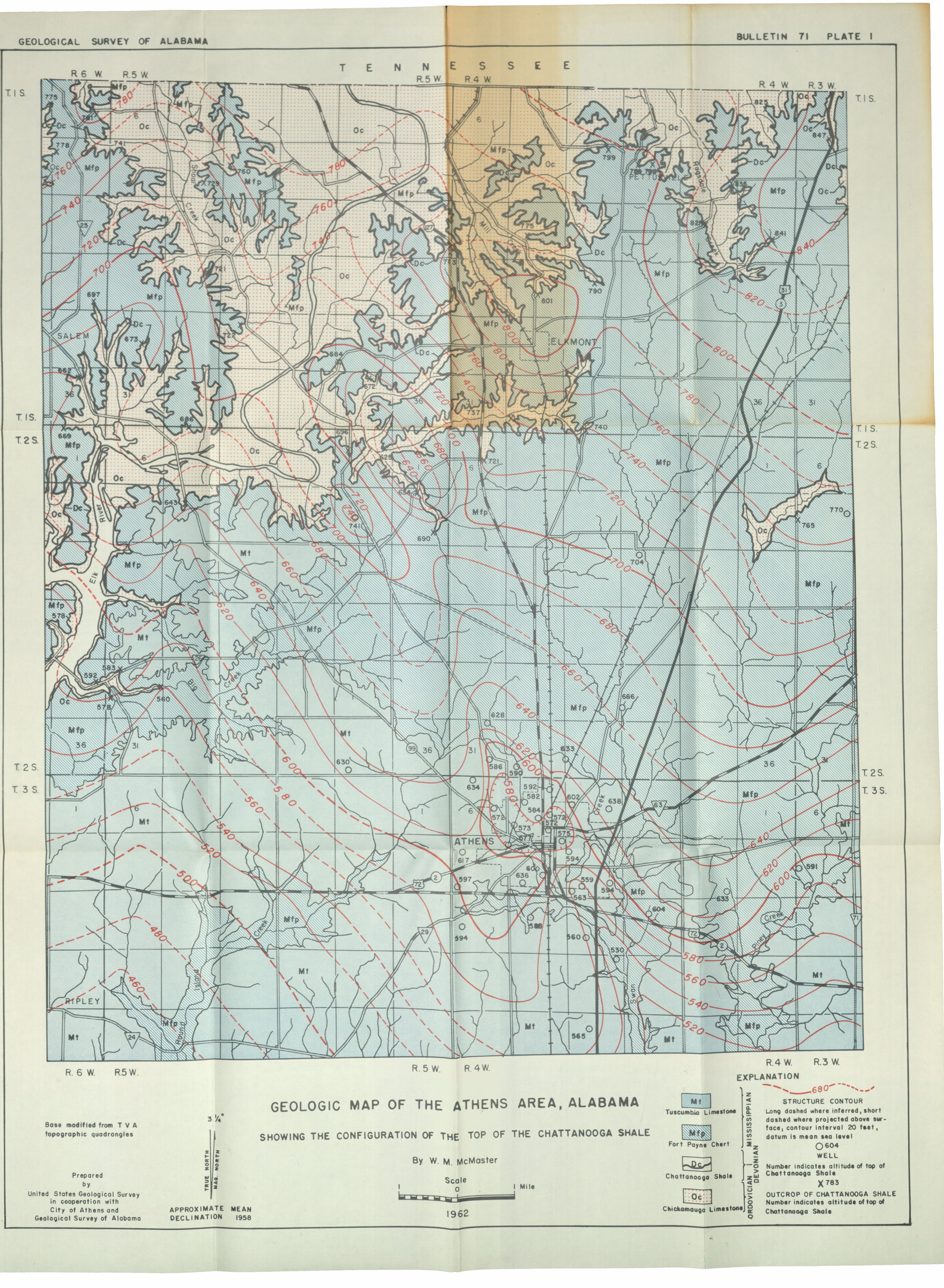
Secondary paved road

Gravel or dirt road

U. S. Highway

State Highway

County Highway



GEOLOGIC MAP OF THE ATHENS AREA, ALABAMA

SHOWING THE CONFIGURATION OF THE TOP OF THE CHATTANOOGA SHALE

By W. M. McMaster

Base modified from T V A topographic quadrangles

Prepared by United States Geological Survey in cooperation with City of Athens and Geological Survey of Alabama

3 1/4° TRUE NORTH MAG. NORTH

APPROXIMATE MEAN DECLINATION 1958

Scale 0 1 Mile

1962

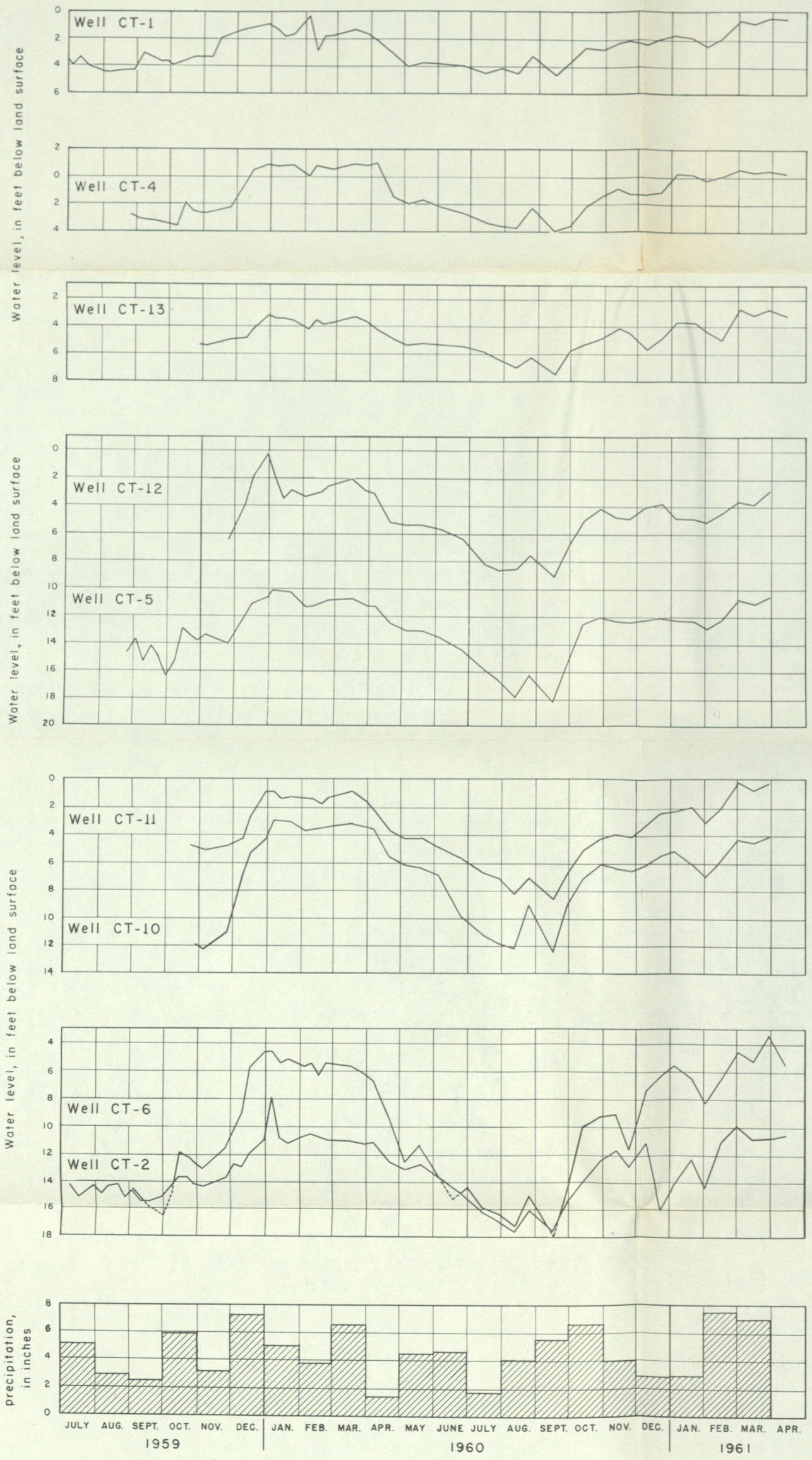
EXPLANATION

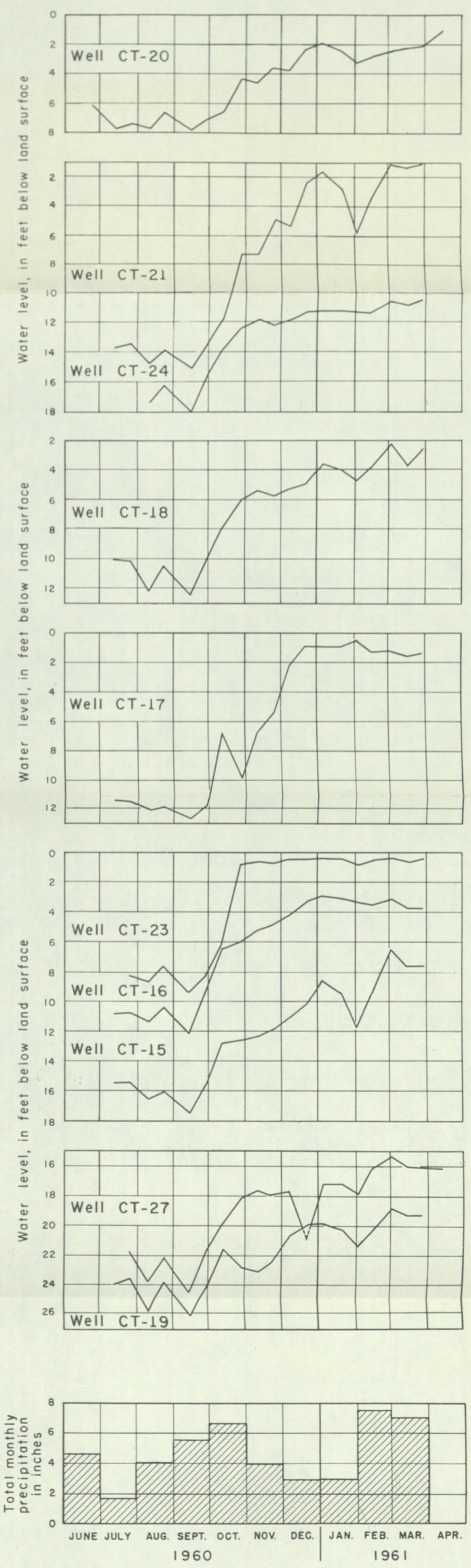
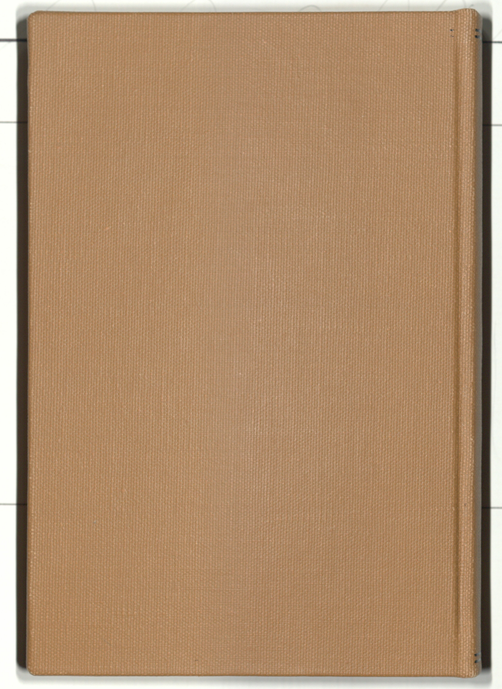
Mt	Tuscumbia Limestone	MISSISSIPPIAN
Mfp	Fort Payne Chert	MISSISSIPPIAN
Dc	Chattanooga Shale	DEVONIAN
Oc	Chickamauga Limestone	ORDOVICIAN

680 STRUCTURE CONTOUR
Long dashed where inferred, short dashed where projected above surface, contour interval 20 feet, datum is mean sea level

○604 WELL
Number indicates altitude of top of Chattanooga Shale

X783 OUTCROP OF CHATTANOOGA SHALE
Number indicates altitude of top of Chattanooga Shale





CHANGES IN WATER LEVEL IN TEST WELLS AND PRECIPITATION AT ATHENS, 1959 - 61.